

EFFECTS OF FLOOD CONTROL WORKS
FAILURE IN THE MISSOURI RIVER BASIN

A thesis presented to the Faculty of the U.S. Army
Command and General Staff College in partial
fulfillment of the requirements for the
degree

MASTER OF MILITARY ART AND SCIENCE
Homeland Security Studies

by

BRADLEY T. COMRIE, MAJOR, UNITED STATES ARMY
B.S., Florida Institute of Technology, Melbourne, Florida, 2002

Fort Leavenworth, Kansas
2014-01

Approved for public release; distribution is unlimited.

REPORT DOCUMENTATION PAGE				<i>Form Approved</i> OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.					
1. REPORT DATE (DD-MM-YYYY) 13-06-2014		2. REPORT TYPE Master's Thesis		3. DATES COVERED (From - To) AUG 2013 – JUNE 2014	
4. TITLE AND SUBTITLE Effects of Flood Control Works Failure in the Missouri River Basin				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Bradley T. Comrie, MAJ, USA				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Command and General Staff College ATTN: ATZL-SWD-GD Fort Leavenworth, KS 66027-2301				8. PERFORMING ORG REPORT NUMBER	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for Public Release; Distribution is Unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT As seen throughout history, flooding is a natural disaster that brings massive amounts of destruction. Flooding interrupts thousands of lives, and costs associated with response and recovery amount to hundreds of millions or even billions of dollars. This thesis looks at the effects of flooding throughout the Missouri River basin. A qualitative methodology utilizing a multi-site case study examines the effects. The cases for this research include the flood events of 1993, 2011, as well as looks at a future threat of a catastrophic earthquake along the New Madrid fault. Areas of emphasis include conditions that lead up to the flood, examples of failed flood control works, economic consequences, loss of human life, policy or projects that came as a result of the flood, and damages prevented by flood control works. Flooding is a disaster that is never 100 percent preventable, but mitigation to the impacts is critical in preventing unnecessary damages and returning to normalcy in the quickest time possible.					
15. SUBJECT TERMS Critical Infrastructure Protection, Flooding, Federal Emergency Management Agency, Dams, Levees, Economy, United States Army Corps of Engineers, Missouri River Basin					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT (U)	18. NUMBER OF PAGES 91	19a. NAME OF RESPONSIBLE PERSON
a. REPORT (U)	b. ABSTRACT (U)	c. THIS PAGE (U)			19b. PHONE NUMBER (include area code)

MASTER OF MILITARY ART AND SCIENCE

THESIS APPROVAL PAGE

Name of Candidate: Major Bradley T. Comrie

Thesis Title: Effects of Flood Control Works Failure in the Missouri River Basin

Approved by:

_____, Thesis Committee Chair
Clay Easterling, M.S.

_____, Member
O. Shawn Cupp, Ph.D.

_____, Member
Stephen V. Tennant, M.S., M.P.A.

Accepted this 13th day of June 2014 by:

_____, Director, Graduate Degree Programs
Robert F. Baumann, Ph.D.

The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

EFFECTS OF FLOOD CONTROL WORKS FAILURE IN THE MISSOURI RIVER BASIN, by Major Bradley T. Comrie, 91 pages.

As seen throughout history, flooding is a natural disaster that brings massive amounts of destruction. Flooding interrupts thousands of lives, and costs associated with response and recovery amount to hundreds of millions or even billions of dollars. This thesis looks at the effects of flooding throughout the Missouri River basin. A qualitative methodology utilizing a multi-site case study examines the effects. The cases for this research include the flood events of 1993 and 2011 as well as look at a future threat of a catastrophic earthquake along the New Madrid fault. Areas of emphasis include conditions that lead up to the flood, examples of failed flood control works, economic consequences, loss of human life, policy or projects that came as a result of the flood, and damages prevented by flood control works. Flooding is a disaster that is never 100 percent preventable, but mitigation to the impacts is critical in preventing unnecessary damages and returning to normalcy in the quickest time possible.

ACKNOWLEDGMENTS

First, I would like to thank my wife, Amber, and my kids, Mallory and Mason. This research took valuable time away from them, and I appreciate their understanding of my absence throughout the year. I would also like to thank my committee, Mr. Tennant, Mr. Easterling, and Dr. Cupp. I appreciate the hours you spent assisting with this endeavor. I will not forget your guidance and encouragement during the year. I owe many thanks to the folks at the Kansas City and Omaha Districts, and the Northwest Division Corps of Engineers. The resources provided and discussions lent to a greater understanding of the Missouri River basin, and USACE's roles and responsibilities within the basin. Finally, I need to thank the instructors of staff group 10A and team 10, Dr. Bradbeer, Dr. Fischer, Mr. Tennant, Mr. Burke, and MAJ Heinonen. You made this year enjoyable, and instilled the desire to continue self-development past this academic year.

TABLE OF CONTENTS

	Page
MASTER OF MILITARY ART AND SCIENCE THESIS APPROVAL PAGE	iii
ABSTRACT	iv
ACKNOWLEDGMENTS	v
TABLE OF CONTENTS	vi
ACRONYMS	viii
ILLUSTRATIONS	ix
TABLES	x
CHAPTER 1 INTRODUCTION	1
Background	1
Primary Research Question	8
Secondary Research Questions	8
Assumptions	8
Definitions	8
Limitations	11
Delimitations	12
Significance of Study	12
Structure of the Paper	13
CHAPTER 2 LITERATURE REVIEW	14
Introduction	14
Federal Government	15
Federal Laws and Regulations	18
Books and Journals	20
1993 Flood	22
2011 Flood	24
New Madrid Scenario	26
Summary	27
CHAPTER 3 RESEARCH METHODOLOGY	29
Introduction	29
Overall Approach and Rationale	29

Case Selection.....	30
Data-Gathering Methods.....	31
Data Analysis Procedures	32
Summary.....	34
 CHAPTER 4 ANALYSIS	 35
Introduction.....	35
The Flood of 1993.....	35
What Environmental Conditions Lead to FCW Failure?.....	37
What Flood Control Works Failed?	37
How Long Did the Flooding Last?	39
What Economic Consequences Resulted From Flooding?	39
How Many Deaths Resulted From Flooding?.....	43
What Federal Projects or Changes to Policy Ensued Because of Flooding?	43
What Damages Did FCW Prevent?	45
The Flood of 2011.....	46
What Environmental Conditions Led Up to FCW Failure?.....	47
What FCW Failed?	49
How Long Did the Flooding Last?	50
What Economic Consequences Resulted From Flooding?	50
How Many Deaths Resulted From Flooding?.....	54
What Federal Projects or Changes to Policy Ensued Because of Flooding?	54
What Damages Did FCW Prevent?	56
New Madrid Scenario	57
What Environmental Conditions Might Lead Up to FCW Failure?	58
What FCW Might Fail?	60
How Long Would the Flooding Last?.....	61
What Economic Consequences Might Result from Flooding?.....	62
How Many Deaths Might Result From Flooding?	62
Flood Event Comparisons.....	63
Summary.....	64
 CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS	 65
Introduction.....	65
Findings	66
What Are the Possible Causes of Failed FCW?.....	66
What Are the Economic Effects From Failed FCW?	66
What Are the Effects on Human Life That May Result From Failed FCW?	67
Conclusion	68
Areas for Further Study	70
Summary.....	71
 REFERENCE LIST	 73

ACRONYMS

DHS	Department of Homeland Security
FCW	Flood Control Works
FEMA	Federal Emergency Management Agency
U.S.	United States
USACE	United States Army Corps of Engineers

ILLUSTRATIONS

	Page
Figure 1. Levee Safety: Shared Responsibility	4
Figure 2. Missouri River Basin	10
Figure 3. 1993 Flood Extent.....	36
Figure 4. 2011 Missouri River Basin Flood Extent.....	47
Figure 5. New Madrid Seismic Zone	58
Figure 6. Missouri Liquefaction Susceptibility	59
Figure 7. Levee Protection near Saint Louis, Missouri.....	61

TABLES

	Page
Table 1. Missouri River Basin Levee Information	7
Table 2. Case Study Data, Blank	33
Table 3. Damage to Key Infrastructure.....	41
Table 4. Key Infrastructure Within Flooded Area	52
Table 5. Damage Comparisons	64

CHAPTER 1

INTRODUCTION

We were heartened by acts of initiative, perseverance, and heroism by local responders and the U.S. Coast Guard but, to add bewilderment and outrage to our sense of tragedy, we were horrified when the response to the Katrina catastrophe revealed—all too often, and for far too long—confusion, delay, misdirection, inactivity, poor coordination, and lack of leadership at all levels of government.

— Senator Susan M. Collins, *Hurricane Katrina: A Nation Still Unprepared*

Background

The failure of flood control works (FCW) has devastating effects in the United States on a reoccurring basis. As a result, many different organizations are involved in protecting, mitigating, responding to, and recovering from failures of these key infrastructures. These organizations range from federal agencies to the private sector at the local level. Coordination is difficult because of different jurisdictions and private sector interests. Many national strategic documents provide guidance in this critical area, including Homeland Security Presidential Directive-7 (published in 2004), The Stafford Act (Amended in 2013), and the National Infrastructure Protection Plan (most recently published in 2013).

In response to the terrorist attacks of 11 September 2001, the federal government realized the need for the creation of an agency to oversee the security and resiliency of the United States in the wake of natural or man-made disasters. There are many different branches within the Department of Homeland Security (DHS), most of which focus on specific aspects of defending the United States. The Under Secretary for National Protection and Programs reports directly to the Secretary of Homeland Security, and

oversees the Assistant Secretary for of Infrastructure Protection (U.S. Department of Homeland Security 2014a). The Office of Infrastructure Protection has overall responsibility for the protection of and response to six areas identified as critical infrastructure and key resources. One of these is the dams sector, which includes dams, levees, navigation locks, and dikes (U.S. Department of Homeland Security 2010, 9). The Department of Homeland Security utilizes the term “dams sector infrastructure” when referring to FCW, the term used by the United States Army Corps of Engineers (USACE).

The Federal Emergency Management Agency (FEMA) bears a large role in the mitigation and response to FCW failure within the United States. In 1979, under Executive Order 12127, FEMA was first formed because of the merger of numerous disaster relief organizations (Federal Emergency Management Agency 2014a). As previously mentioned, DHS is responsible for the safety of the United States. A major piece of protecting the homeland includes preparing for and mitigating the effects of natural disasters, which is part of the core mission for FEMA. Per the Homeland Security Act of 2002, FEMA falls under DHS to assist in this role (U.S. Congress 2002, §503). The Federal Emergency Management Agency is organized into 10 regions across the United States. Two FEMA regions cover the majority of the Missouri River basin with the exception of the southeast corner of Minnesota. Region VII is responsible for implementing FEMA’s mission in Missouri, Kansas, Nebraska, and Iowa, while Region VIII maintains responsibility for North Dakota, South Dakota, Montana, Wyoming, Colorado, and Utah (Federal Emergency Management Agency 2014a).

The United States Army Corps of Engineers has a large role in FCW failure mitigation and response. The lineage of USACE traces back to the appointment of the first Chief of Engineers on 16 June 1775. In 1824, Congress passed two laws that established USACE's responsibility for U.S. waterways: The authorization to survey roads and canals of national importance, and appropriations to improve navigation of the Ohio and Mississippi rivers, known as the Rivers and Harbors Act (U.S. Army Corps of Engineers 2014b). Over time, USACE gained more responsibilities for constructing and maintaining infrastructure along navigable waterways in the United States. Within USACE, the Civil Works Directorate is responsible for federally owned and maintained FCW. The mission of the Civil Works Directorate includes, but is not limited to flood risk management, navigation, and emergency response (U.S. Army Corps of Engineers 2014a).

Specifically within USACE, the Northwest Division oversees two districts that conduct much of the day-to-day operations of the navigable waterways within the Missouri River basin and the six main stem dams on the Missouri River. The Northwest Division came into existence in 1997 when the Missouri River Division and North Pacific Division merged (U.S. Army Corps of Engineers 2014d). Within the Missouri River basin, the Kansas City District and the Omaha District are responsible for civil works. The Kansas City District is responsible for the Missouri River basin in Kansas, the majority of Missouri, and small portions of southern Nebraska and eastern Colorado. The Omaha District is responsible for the remainder of the Missouri River basin to the north and west, including portions of Missouri, Colorado, Nebraska, Iowa, Minnesota, South Dakota, North Dakota, Montana, and Wyoming. Along the Missouri River, The Omaha

District is responsible for the operation and maintenance of the six main stem dams: Fort Peck, Garrison, Oahe, Big Bend, Fort Randall, and Gavins Point. The United States Army Corps of Engineers manages these dams as a single system with the primary purpose of navigation, flood control, hydroelectric power, and irrigation (U.S. Army Corps of Engineers 1993, 176).

The Federal Emergency Management Agency and USACE both have many responsibilities for flood mitigation and response. Their roles are distinct, but mutually supporting. Figure 1 is an example of how the two agencies provide mutual support to local communities, and what responsibilities lay with the community in regards to levee safety. In this case, local community includes local government and/or private sector owners.

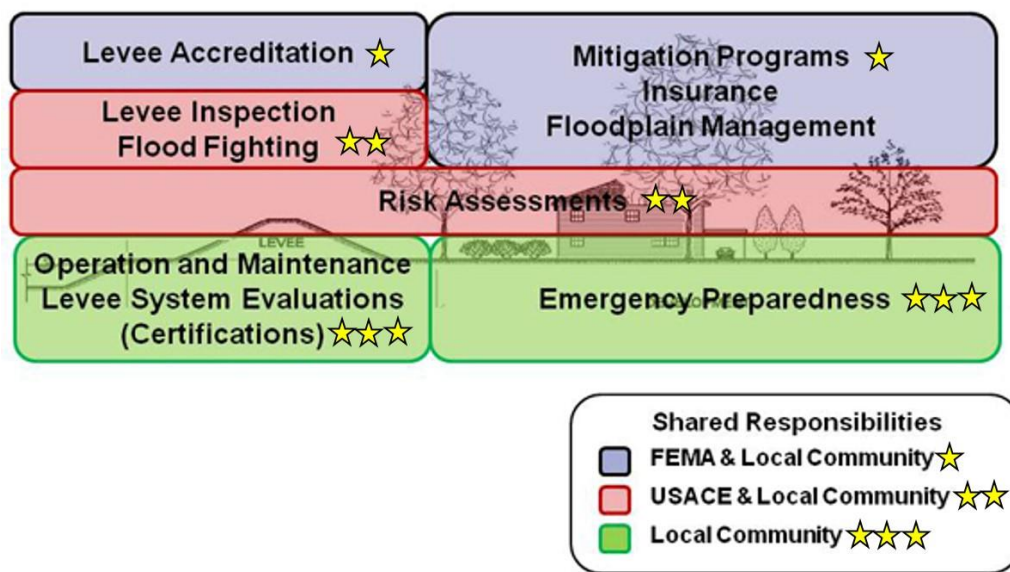


Figure 1. Levee Safety: Shared Responsibility

Source: U.S. Army Corps of Engineers, USACE/FEMA/Community Partnership, <http://www.usace.army.mil/Missions/CivilWorks/LeveeSafetyProgram/USACEFEMACommunityPartnership.aspx> (accessed 12 February 2014).

Flood control works operated and maintained by non-federal sponsors may receive funding under the USACE rehabilitation and inspection program. The purpose of the rehabilitation and inspection program is to ensure the continuation of reliable flood damage protection for human life, communities and improved property (U.S. Army Corps of Engineers 2001a, 5-1). There are multiple ways FCW incorporate into the Rehabilitation and Inspection Program including inspection of completed works, and initial and continuing eligibility inspections. The record of this program is maintained as the National Levee Database. These ways. Inspection of completed works addresses federal constructed projects turned over to non-federal sponsors for operation and maintenance, and initial eligibility inspections addresses non-federal FCW projects (U.S. Army Corps of Engineers 2001a, 5-4 – 5-6). Once accepted into the rehabilitation and inspection program, continuing eligibility inspections must monitor change to projects from previous inspections (U.S. Army Corps of Engineers 2001a, 5-8). Flood control works that are accepted into the program are eligible to receive federal funds to repair damages prior to or following a flood event while in active status. In the event of damage due to a flood, repairs are limited to pre-disaster level of protection, but design and materials improvements occur when accepted engineering practices have advanced since the original design (U.S. Army Corps of Engineers 2001b, 5-1). This allows structures to provide increased protection or allows for a more economically feasible repair when engineering practices have progressed since the initial construction. If a FCW fails to meet inspection standards described in Engineer Regulation 500-1-1, the structure enters into an inactive status and will not receive funding in the event of damage. In addition, USACE will inform FEMA of the status of uncertified FCW under the National Flood

Insurance Program, which will result in the denial of insurance funds (U.S. Army Corps of Engineers 2001b, 5-9).

State and local governments play an important role in regards to FCW within the Missouri River basin. Typically, before a higher echelon of government becomes involved in the response to a disaster, the lower level must declare a state of emergency. Once local or state resources become overwhelmed, a national state of emergency is declared. This allows FEMA to respond and assist with the disaster response.

The United States Army Corps of Engineers does not have to wait for an emergency declaration in order to respond to imminent or ongoing flooding if certain circumstances exist. The United States Army Corps of Engineers may provide emergency assistance under Public Law 84-99 to save lives and protect improved properties during or following a flood (U.S. Army Corps of Engineers 2001b, 4-1). This allows USACE to increase responsiveness, thereby mitigating potential damage. In order to provide response the USACE district must make a declaration of emergency, which the District Commander may delegate as low as the Chief of Emergency Management (U.S. Army Corps of Engineers 2001b, 4-1).

Non-federal government or the private sector owns most of the FCW in the Missouri River basin. This can create difficulties in maintaining protection of the system as a whole. Table 1 is derived from USACE's National Levee Database, and shows all non-federal or private sectors that operate and maintain levees within the Missouri River Basin.

Table 1. Missouri River Basin Levee Information			
	Missouri River Basin	Kansas City District	Omaha District
Number of Levees Constructed by USACE, Operated and Maintained by Public Sponsor	186	57	129
Number of Levees Locally Constructed, Operated and Maintained	154	127	27
Miles of Levee Constructed by USACE, Operated and Maintained by Public Sponsor	979.87 Miles	388.83 Miles	591.04 Miles
Miles of Levee Locally Constructed, Operated and Maintained	873.74 Miles	799.92 Miles	73.82 Miles
Number of Active Levees in RIP	279	136	143
Number of Inactive Levees in RIP	61	48	13
Miles of Active Levee in RIP	1655.97 Miles	1037.45 Miles	618.52 Miles
Miles of Inactive Levee in RIP	197.64 Miles	151.3 Miles	46.34 Miles

Source: Created by author, utilizing data from U.S. Army Corps of Engineers, National Levee Database, <http://nld.usace.army.mil/egis/f?p=471:58:1194862640275401::NO> (accessed 31 March 2014).

Along the Missouri River, there are forty-four dams that have a primary purpose of flood control; the federal government controls only sixteen of those dams (U.S. Army Corps of Engineers 2014f). Fourteen of the forty-four flood control dams are considered a high hazard potential, which means failure or miss-operation will probably cause loss of life, resulting in economic loss, environmental damage, and disruption of lifeline facilities (U.S. Army Corps of Engineers 2014f). Of the fourteen high hazard potential dams on the Missouri River, five are not managed by the federal government (U.S. Army Corps of Engineers 2014f).

Primary Research Question

The primary research question is what are the effects of failed flood control works in the Missouri River Basin? Depending on weather and soil conditions, large scale flooding from failed FCW can have a devastating and lasting effect on communities.

Secondary Research Questions

Secondary questions that are what are possible causes of flood control works failure? What are the economic effects from failed flood control works? What are the effects on human life that may result from failed flood control works?

Assumptions

Assumptions made during research include that the following:

1. Consolidation of the responsibility of FCW will not occur under one government agency.
2. Flood Control Works experience varying levels of vulnerability due to environmental conditions.
3. Human error will affect the prevention of and response to FCW failure.
4. Nature is uncontrollable and detrimental effects will occur because of failed FCW regardless of mitigation efforts.
5. If FCW did not exist in the areas observed through the case studies presented in chapter 4, people would continue to live and work within the floodplains.

Definitions

Critical Infrastructure: Systems and assets, whether physical or virtual, so vital to the United States that the incapacity or destruction of such systems and assets would have

a debilitating impact on security, national economic security, national public health or safety, or any combination of those matters (U.S. Congress 2001, §5195c).

Dams Sector: Comprises dam projects, hydropower plants, navigation locks, levees, dikes, hurricane barriers, mine tailings and other industrial waste impoundments, and other similar water retention and water control facilities (U.S. Department of Homeland Security 2010,1).

Defense Support of Civil Authority: Support provided by U.S. federal military forces, Department of Defense civilians, contract personnel, component assets, and National Guard (when the Secretary of Defense, in coordination with Governors of affected States, elects and requests utilization in Title 32 status) in response to domestic emergencies (U.S. Joint Chiefs of Staff 2013, vii).

Emergency: Any occasion or instance requiring federal assistance to supplement state and local efforts and capabilities to save lives and to protect property and public health and safety, or to lessen or avert the threat of a catastrophe in any part of the United States as determined by the President (U.S. Congress 2013, §102).

Flood Control Works: Structures designed and constructed to prevent damages caused by irregular and unusual rises in water level, which may include levees, channels, floodwalls, dams (Department of the Army 2001a, Glossary-7).

Major Disaster: Any catastrophe . . . regardless of cause, any fire, flood, or explosion, in any part of the United States, which in the determination of the President causes damage of sufficient severity and magnitude to warrant major disaster assistance . . . to supplement the efforts and available resources of States, local governments, and

disaster relief organizations in alleviating the damage, loss, hardship, or suffering caused thereby (U.S. Congress 2013, §102).

Missouri River Basin: The Missouri River basin has an area of 529,000 square miles covering Montana, Wyoming, Colorado, North Dakota, South Dakota, Nebraska, Minnesota, Iowa, Kansas, and Missouri in the United States, and Alberta and Saskatchewan in Canada (U.S. Army Corps of Engineers 1998, 1). The major river that flows through the basin is the Missouri River, which begins near Three Forks, Montana, and empties into the Mississippi River in Saint Louis, Missouri.

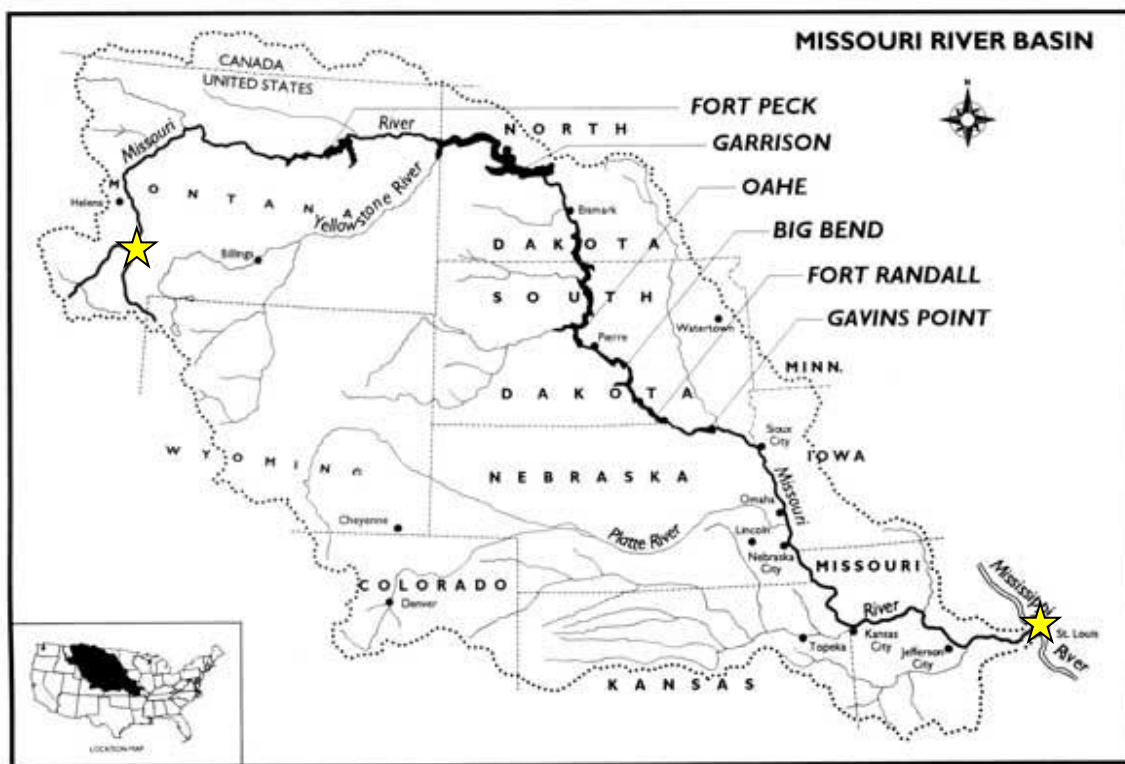


Figure 2. Missouri River Basin

Source: Missouri Department of Natural Resources, http://www.dnr.mo.gov/env/wrc/interstwttrs/missouri_river.htm (accessed 9 March 2014).

Navigable Waterways: Waters that are subject to the tide, and/or are used presently or in the past, or have the potential for use in the future for interstate or foreign transport (Code of Federal Regulations, Title 33, Sec. 329.4).

Limitations

Many levels and sectors of government are involved in disaster preparedness and response. Due to numerous jurisdictions in the area of FCW, research will not examine all government agencies and private sectors involved. This also limits access to all reports and studies completed on the topic. Historical instances of FCW failure caused significant effects within the area of study, but limited information is available to the researcher based on what is available to the public. Due to the large size of the area of study, the researcher will not be able to meet with all federal organizations involved in flood control. Given the time and data available, the researcher will not separate damages caused from excessive rainfall compared to damages directly related from failed FCW. Additionally, damages cannot be differentiated between levees that failed due to a breach or overtopping in conditions less than the design versus overtopping in conditions exceed the design. Time allotted for this research does not allow exact calculation of dollar amounts for damages because FEMA regions do not mirror USACE civil works boundaries. For example, FEMA Region VII encompasses all of Missouri, USACE Kansas City District only encompasses the area of Missouri within the Missouri River basin. Extrapolation of some data is unfeasible in the allotted time because the flooding that occurred in 1993 encompassed an area larger than the Missouri River basin. When feasible, the information provided in this research will reference data within the Missouri River basin.

Delimitations

The amount of FCW within the Missouri River basin is too great to look at all possible scenarios. This prevents the author from examining all effects of failure that exist in the area of study. It is important to look at the Missouri River basin as an entire system because failure of FCW on a tributary may affect the larger system. Because of the time available, it is not feasible to look at all effects from previous FCW failures. The author will not determine the effects separately of each individual FCW failure within each case study. Depending on if two or more FCW failed in close proximity, it is not feasible to separate the effects of each failure. Finally, this research will not analyze environmental effects on sediment transport, flora, or fauna caused by failed FCW within the Missouri River basin.

Significance of Study

Large-scale disasters, natural or manmade, are of great concern. It is imperative to look at the effects of failed FCW in order to understand where risks exist and ways to mitigate those risks. Because it is not possible to prevent flooding, understanding effects allows everyone from the private sector to the federal government to gain a better understanding of risks involved in decision-making. Examples of these decisions include what FCW projects to fund, and where to assume risk. Additionally, knowing the effects or possible effects of flooding is imperative in budgeting at all levels of government. Because there is limited funding for flood protection, the risks (partially determined by studying effects) inform cost-benefit analysis and prioritizing future flood control works projects.

Structure of the Paper

The presentation of this research occurs in five chapters. Chapter 1 is the introduction, and presents background information on the federal agencies involved in multiple aspects of FCW and key definitions within the topic. It also provides the purpose of this paper and the research questions, as well as limitations and delimitations during the study. Chapter 2 provides a review of literature related to FCW. The review discusses strategic documents at the federal level to include applicable laws, regulations, and plans related to FCW and homeland security in general. It also reviews documents pertinent to the case study analysis on the floods of 1993 and 2011, and a theoretical scenario of significant seismic activity along the New Madrid fault presented in chapter 4. Chapter 3 discusses the research methodology utilized in this study. It further defines criteria for choosing case studies, data collection, and data analysis procedures. Chapter 4 provides the findings for the primary and secondary research questions in narrative format pertaining to the three case studies. The fifth and final chapter provides a brief summary of the findings presented in chapter 4, and provides a conclusion and recommendations.

CHAPTER 2

LITERATURE REVIEW

Introduction

The purpose of this thesis is to examine the effects of failed FCW along the Missouri River basin. There is a wealth of information about infrastructure failure related to waterways in the United States. The majority of the information comes from analysis of large-scale floods along the Missouri River and its tributaries or the possible effects of a large dam failure. Federal government agencies, including the DHS and the USACE, produce much of the information. Because of the importance of this infrastructure to the United States, many laws exist that pertain to FCW. Many researchers are writing on the topic because of the immense impact that this topic has along numerous disciplines. Flood control works involves disciplines such as engineering, environmental science, economics, and public policy. Most books available today do not focus specifically on FCW, but provide a holistic view pertaining to all critical infrastructure and key resources.

This chapter presents information in four main sections. The first section includes important references produced by the federal government, the second reviews federal laws that affect FCW. The third and fourth sections present scholarly information from books and journals, and publications related directly to the case studies analyzed in chapter 4 respectively.

Federal Government

The responsibility of protecting the United States from both terrorist attacks and natural disasters falls to DHS, which is the primary agency responsible to implement the National Strategy for Homeland Security. The Protection and Program Directorate, led by an Under Secretary, is responsible for directing the protection of critical infrastructure. Within this directorate, the Office of Infrastructure Protection maintains the responsibility for publishing all infrastructure protection, capstone documents. These provide direction for all subsequent policy documents written by the federal government regarding infrastructure protection.

Before looking at literature related directly to FCW, it is important to discuss key documents related to emergency response in general. Two documents produced by DHS are critical for planning, preparing, or responding to incidents within the United States. The National Incident Management System (2008) and the National Response Framework (2013) provide the basic doctrine for emergency response. The National Incident Management System provides a template for managing incidents, while the National Response Framework gives organization and tools for federal policy regarding incident management (U.S. Department of Homeland Security 2008, 1). The National Incident Management System is broken down into five components: preparedness; communications and information management; resource management; command and management; and ongoing management and maintenance. It describes how the private sector, local, state, and federal governments synchronize efforts in planning and preparing for or in response to an incident. It is conceptual and scalable for use at any level of response.

The National Response Framework is a strategic document published by DHS that guides how the nation will respond to any type of disaster or emergency within the United States (U.S. Department of Homeland Security 2013, 1). This document provides examples of roles and responsibilities at all levels of incident response. Not all actions are required for every incident, which is why this document is a framework instead of a statutory regulation. In addition to the National Response Framework, emergency support function, incident, and support annexes provide additional guidance.

A key document produced by the federal government is the Dams Sector-Specific Plan published in 2010. This document nests under the National Infrastructure Protection Plan published in 2009. The Department of Homeland Security published an updated version of the National Infrastructure Protection Plan in 2013 in response to the Presidential Policy Directive-21, but an updated of the Dams Sector-Specific Plan is yet to be published (U.S. Department of Homeland Security 2014b). Publication of these strategies typically occurs in response to an updated National Security Strategy, which drives all subsequent strategic documents for the federal government.

The Federal Emergency Management Agency (FEMA) has the mission of supporting United States citizens and first responders to build, sustain, and improve the capability to prepare for, protect against, respond to, recover from, and mitigate all hazards (Federal Emergency Management Agency 2013). The Federal Emergency Management Agency prepares many strategic documents relating to disaster recovery, and gains experience in the field on a daily basis, and assisted with thirty-nine major disaster declarations and two emergency declarations because of flooding in in 2013 (Federal Emergency Management Agency 2014b).

The Federal Emergency Management Agency's Strategic Plan for 2011-2014 does not specifically address FCW, but lays the foundation for subsequent strategies. This strategic plan focuses on four key initiatives to accomplish their mission, which are to foster a whole community approach to emergency management nationally; build the nation's capacity to stabilize and recover from a catastrophic event; build unity of effort and common strategic understanding among the emergency management team; and enhance FEMA's ability to learn and innovate as an organization (Federal Emergency Management Agency 2011, 7). In 2012, FEMA published the Strategic Plan for the National Dam Safety Program, which lays out the strategy through 2016. This plan has five goals: reduce the likelihood of dam failures; reduce the potential consequences resulting from dam failures; promote public awareness of the benefits and risks related to dams; promote research and training for state dam safety and other professionals; and align federal programs to improve dam safety (Federal Emergency Management Agency 2012, iv).

The United States Army Corps of Engineers serves many important roles in regards to the major waterways. As the lead government agency for maintaining the waterway to include many of the dams, locks, and levees, the Corps of Engineers is the foremost technical expert on these systems. The Corps of Engineers writes and maintains hundreds of publications relating to FCW to include engineering regulations, manuals, circulars, design guides, and technical letters. Two important engineer regulations in regards to mitigation in the event of a failure include ER 500-1-1 (Civil Emergency Management Program), and ER 500-1-28 (National Response Planning Guide). The Civil Emergency Management Program regulation lays the foundation for the way in which

USACE provides mitigation and response in the event of a disaster, to include FCW failure. Under the Stafford Act, FEMA may direct USACE, through the Department of Defense, for use of personnel, resources, and other means necessary in the event of a major disaster or emergency declaration (Department of the Army 2001b, 2-1). This regulation also mandates that USACE provide personnel to serve on hazard mitigation teams. Hazard mitigation teams are interagency teams that provide mitigation strategies within fifteen days following a major disaster declaration by the President of the United States (Department of the Army 2001a, 8-1). The National Response Planning Guide regulation provides direction to USACE for the implementation of Emergency Support Function #3, an annex to the National Response Framework. The Department of Defense designated USACE as the lead federal agency for the planning and execution of Emergency Support Function #3 missions in support of FEMA (Department of the Army 2001, 1-1).

Federal Laws and Regulations

The Stafford Act provides the overarching guidance to federal agencies on how to provide assistance in the event of an emergency or natural disaster. It provides statutory regulations on how and when to respond, as well as fiscal support, to state and local governments and federal disaster relief. The Disaster Mitigation Act of 2000 expounds upon mitigation procedures stated in the Stafford Act. It requires states to submit a mitigation plan to the President in order to receive an increased share of up to 20 percent in the event a major disaster does occur in areas covered by the mitigation plan (U.S. Congress 2000, §322).

The Post Katrina Emergency Management Reform Act of 2006 modified the way in which FEMA operated. It also mandated FEMA to reduce the loss of life and property and protect the United States from all hazards by leading and supporting the nation in a comprehensive, risk-based emergency preparedness and response program of mitigation, preparedness, response, recovery and critical infrastructure protection (U.S. Congress 2006, §513). Congress also directed a comprehensive review and update of the National Response Plan, now called the National Response Framework (U.S. Congress 2006, §403). These changes provide a clear chain of command and improve communications between all agencies involved in response to an emergency or major disaster.

The National Levee Safety Program Act of 2007 lays out the responsibilities of the Secretary of the Army concerning levee safety for action by USACE. Requirements include levee inspections, and recommendations of priorities for which levees to repair. Specifically, it outlines the requirement to inspect levees every five years that pose a significant threat to human life and public property if failure occurs (U.S. Congress 2007, §7). This act also provided a budget that was in effect through fiscal year 2013. An updated budget beyond fiscal year 2013 was not available for this research. The National Dam Safety Program Act of 1996 directed FEMA to establish a dam safety program in coordination with the nine other federal agencies (U.S. Congress 1996, §5). This law directs focus on six objectives: development of programs and procedures for hazard reduction; encourage acceptable engineering policies and procedures; encourage states to participate in dam safety; encourage public awareness; develop technical assistance materials; and develop mechanisms to technically assist the non-federal sector.

Additionally, the three functional activities include leadership, technical assistance, and public awareness.

Books and Journals

Since the attacks that occurred on 11 September 2001, many publications have emerged on protecting critical infrastructure. Two journals in publication focus specifically on infrastructure protection; The *International Journal of Critical Infrastructure Protection* (established 2008), and the *International Journal of Critical Infrastructures* (established 2004). Both of these journals provide a great deal of knowledge on critical infrastructure, but only a small fraction of the articles relate specifically to FCW.

Hundreds of books exist on the topic of critical infrastructure protection. Like the journals, they tend to focus broadly on critical infrastructure vice providing specifics related directly to FCW. *Protection of Civilian Infrastructure from Acts of Terrorism* in the NATO Security through Science Series contains a chapter specifically devoted to large dams. Even though this book speaks directly to terrorist attacks on dams, it concludes the threat is real, but not as significant or as powerful as nature (Frolov and Baecher 2006, 106). This chapter discusses numerous models. British Columbia Hydro Life Safety Model is the focus of the remainder of the material on dams. This model provides two perspectives: a static view that describes long-term characteristics, and a dynamic view that describes a snapshot at any given point in time (Frolov and Baecher 2006, 107). Both perspectives are important to examine in the case of flooding. The static view is more appropriate for long term flooding, while the dynamic view is more suited for flash flooding.

Another book, *Protecting the Homeland 2006/2007*, provides context on incentives for private sector involvement, as well as the roles of the Department of Defense and first responders. Peter Orszag and Michael O'Hanlon propose that the federal government has provided few incentives to the private sector, and therefore little effort is underway to harden infrastructure (d'Arcy et al. 2006, 73). If true, this is critical since the private sector owns the majority of dams in the United States.

Ted Lewis's book, *Critical Infrastructure Protection in Homeland Security*, provides a quantitative view on vulnerability and risk in relation to critical infrastructure. Once again, the book does not specifically focus on FCW, but methods discussed are applicable whether the infrastructure requiring protection is physical or digital. Lewis provides background on the strategy for critical infrastructure protection and challenges that the United States faces. A key concept he discusses is the difference between fault and risk reduction. Risk reduction focuses more specifically on the outcomes of a failure, where fault reduction tends to ignore damages and examines ways to prevent a failure from occurring (Lewis 2006, 177). Because of the large geographic area FCW covers, it is unfeasible to utilize the fault reduction method everywhere. Both fault and risk reduction techniques are necessary at critical nodes such as high capacity dams. It is obvious that the avoidance of faults is critical, but in the event of a failure, risk reduction techniques should be in place for any contingency.

Terrorism and Homeland Security, by Philip Purpura focuses on terrorism inside the United States or its territories. Much in this book is relevant to FCW because whether a failure is natural or man-made, the result does not differ significantly. One area that could pose a distinct difference though, is public perception. Many United States citizens

will criticize the government in some form regardless of the cause of infrastructure failure, but the possibility exists for longer-term damage to the public psyche in the wake of an act of terrorism. Three of Purpura's chapters provide valuable information to this thesis: Private Sector Action (Chapter 6); Risk Management and Emergency Management (Chapter 7); and Protecting Critical Infrastructures and Key Assets (Chapter 10). While the federal government is responsible for preventing terrorist acts, the private sector is responsible for taking reasonable precautions (Purpura 2007, 362). This is critical since private ownership of FCW is the norm, and the federal government does not have the resources available to plan for and mitigate all failures that may occur. A risk management approach that Purpura discusses is the Government Accountability Office approach, which includes threat, vulnerability, and criticality assessments (Purpura 2007, 244). Using only three focus areas may seem easy, but each assessment has multiple technical sub-categories that may contribute to the overall risk assessment. When viewed through a FCW lens, the threat may include the likelihood of a rain event compounded with previous rainfall totals within the same season, and the snowpack and rate of snowmelt. Vulnerability may be the age or composition of a dam, or previous problems in a specific area of a levee. An example of criticality is the amount of water the infrastructure retains, or the affected population in the event of a failure.

1993 Flood

The United States Army Corps of Engineers published *The Great Flood of 1993 Post-Flood Report* in September of 1994. In addition to the base report, two appendices provide important literature for this study. Appendix D is the Omaha District report, and Appendix E is the Kansas City District report. The base report provides a general

description of areas effected by flood, as well as a historical overview and comparison to previous floods in the Mississippi River and Missouri River basins. Additionally the report provides a description of weather and environmental conditions leading up to flood. Numerical data for flow levels and storage reservoirs operated by USACE are also included. The discussion of emergency management procedures and recovery operations conducted by USACE occur further into the report. Finally, the report details general appraisal of damages and lessons learned because of the flood.

In June of 1995, USACE published a follow on report to the September 1994 Post-flood report. This report, *Floodplain Management Assessment of the Upper Mississippi River and Lower Missouri Rivers and Tributaries*, provides additional information relevant to the 1993 floods. Congress appropriated funds under Public Law 103-126 for USACE to conduct the comprehensive study to assess flood control and floodplain management in the areas that flooded in 1993 (U.S. Army Corps of Engineers 1995, 1). The United States Army Corps of Engineers identified eleven objectives for this study, of which seven are applicable to this research. Those seven objectives are: describe resources; array uses; describe impact forces; array actions; document; and present conclusions; evaluate cost effectiveness of alternatives; and recommend improvements to flood control.

The U.S. Geological Survey published a report in 1998, titled *Summary of Floods in the United States, January 1992 through September 1993*. This report provides short summaries, typically three to five pages, on each flood event across the United States over this 21-month period. Included in these summaries are the floods that occurred in East-Central Nebraska in March 1993, South-Central North Dakota in July and August

1993, and Northwest and Central Missouri in September 1993. This report does not cover the entire Missouri River basin or all flooding within, but does provide data on specific flood events within the basin.

In August of 1995, the U.S General Accounting Office produced a report titled *Midwest Flood: Information on the Performance, Effects, and Control of Levees*. This report came at the request of two members of Congress, the Honorable Robert A. Borski and the Honorable William L. Clay. Included in the document are details about specific levee failures including overtopping and breaching. It also compares the possible effects if levee systems had not been in place at all versus what the actual effects in terms of economic costs.

2011 Flood

The *Post 2011 Flood Event Analysis of Missouri River Mainstem Flood Control Storage*, published by USACE in April 2012, provides analysis on the effect of creating additional flood control storage on the Missouri River. It also describes the impact additional flood control storage would have on the other authorized purposes of the Missouri River mainstem dams, which include, but are not limited to navigation, hydropower, irrigation, and recreation. Overall, this report provides valuable data on the effects of flooding in terms of future projects.

In May 2012, the National Weather Service produced a service assessment titled *The Missouri/Souris River Floods of May–August 2011*. This assessment describes environmental conditions leading up to the floods of 2011, and provides recommendations for ways to improve how the National Weather Service meets its mission requirements. In conducting this assessment, the team included nine individuals:

four members from the Weather Forecasting Office, two members from the River Forecasting Center, two hydrologists, and one person from USACE (National Weather Service 2012a, 2).

In October 2012, USACE produced a two-volume document titled *Missouri River Flood 2011 Vulnerabilities Assessment Report*. The first volume is the summary, and the second volume is the technical report. The summary describes an overview of the flood and damages, and describes the methodology for post flood activities, which are repair-restore-enhance. The technical report provides further details on the effects of the flood, the effectiveness of the FCW system, and communications with all parties involved. In addition, the report presents findings of weaknesses and recommendations on how to improve the system and prepare for the next major flood event.

The Missouri River Flood: An Assessment of the River Management in the 2011 and Operational Plans for the Future presents information from the hearing before the Subcommittee on Water Resources and Environment given on November 2011. The hearing presented testimony from members of congress, USACE, and numerous stakeholders in the Missouri River basin. It provides information on the effects of the flood, and examples of budget appropriations related to the authorized purposes of the structures within the Missouri River basin. This document provides inputs from a wide background that include differing views on the effects of FCW.

The Review of the Regulation of the Missouri River Mainstem Reservoir System During the Flood of 2011 is a review of USACE's operations of the reservoir system by an independent panel. The panel of four personnel included Dr. Neil Grigg, a former professor of civil and environmental engineering at Colorado State University; Cara

McCarthy, a hydrologist with the National Resources Conservation Service; Bill Lawrence, a hydrologist with the National Weather Service; and Darwin Ockerman, a hydrologist with the U.S. Geological Survey. During the original scope of the study, USACE provided the panel with twelve questions. These questions included topics such as weather and runoff forecasting, and planned and executed operations in accordance with the Missouri River Master Manual. In addition to the twelve questions provided by USACE, the panel looked at five additional questions. These questions focused on the management and utilization of the flood control system.

New Madrid Scenario

In 2011, DHS, in coordination with other agencies, conducted National Level Exercise 2011, which included a simulated earthquake along the New Madrid fault line. Two documents resulting from this exercise include a review by the DHS Office of Inspector General and a quick-look report produced by FEMA. While these documents do not speak directly to the effects of failed FCW, it is important to know that this scenario is plausible, and that the federal government has contingency plans and rehearses those plans.

In 2009, the Mid-America Earthquake Center published a two-volume report titled the *New Madrid Seismic Zone Catastrophic Earthquake Response Planning Project*. The Federal Emergency Management Agency provided project funding to the Mid-America Earthquake Center, but the assessments and comments are not necessarily those of FEMA (Elnashai et al. 2009a, iii). The first Volume discusses the modeling techniques utilized and an overview of the impact assessment. Volume 2 contains the detailed methodology and results, and is broken down into thirteen appendices.

Specifically within Volume 2, Appendices 5, 7, and 8, Direct Damage and Economic Losses, Maps for Direct Damage and Economic Loss, and Flood Risk Modeling, respectively, provide information useful to this research. The report provides analysis on eight states in close proximity to the New Madrid fault: Missouri, Alabama, Arkansas, Illinois, Indiana, Kentucky, Mississippi, and Tennessee. Of interest to this research is the analysis within Missouri as the Missouri River basin does not extend into the other States.

Another report published by the Mid-America Earthquake Center in 2007 is the *New Madrid Seismic Zone Catastrophic Earthquake Response Planning*. This report looks at the same eight states as noted in the 2009 report, but focuses on five specific population centers, one of them being Saint Louis, Missouri. Saint Louis is the area of convergence between the Missouri River and the Mississippi River, and the southeastern-most portion of the Missouri River basin. In conducting the impact analysis, this report compares three separate epicenters within the New Madrid seismic zone: northeast, central, and southwest (Cleveland, Elnashai, and Pineda 2007, 44).

Summary

This literature review provides a general understanding of the information available in regards to infrastructure protection, and more specifically of FCW. A wide variety of information is available ranging from government-produced publications and federal laws to books, journals, and reports provided by the private sector. Different perspectives emerge when reviewing the literature. Government published information tended to focus on policy and procedures for mitigating, preparing, and responding to failed FCW. Books and journals tended to focus on how to improve systems currently in

place, and provided an emphasis on the criticality of protecting this infrastructure. Gaps that currently exist in literature include the deaggregation of data by area or sector. Data tends to include rollups of large geographic areas instead of presenting by county, levee district, or towns. Effects of failed FCW are not always available by specific sectors. For example, damages are expressed as combined economic consequences instead of separating by transportation, energy, costs associated with emergency work, etcetera.

CHAPTER 3

RESEARCH METHODOLOGY

Introduction

The purpose of this research is to determine the effects of Flood Control Works (FCW) failure in the Missouri River basin. chapter 3 will discuss the research methodology chosen to answer the primary and secondary research questions discussed in chapter 1. John W. Creswell's book, *Qualitative Inquiry and Research Design*, is the primary text utilized in developing the research methodology. This chapter will focus on the overall approach, site selection, data-gathering methods, and data analysis procedures utilized to answer the research questions (Creswell 2007, 49).

Overall Approach and Rationale

The methodology used to answer the primary and secondary research questions is a qualitative approach. A qualitative study presents the best research methodology because the effects of failed FCW are difficult to express simply with numbers. In a small or controlled environment, this would be possible, but because the Missouri River basin does not allow for a controlled environment, qualitative study will best assist in answering the research questions. In addition, the population within a given area complicates the environment and effects of flooding. Because people react differently across a population, it is nearly impossible to describe effects in a quantitative approach. Additionally, a small sample size examined across the Missouri River basin leads to extrapolation of data, which leads to errors within quantitative analysis.

Specifically, a multi-site case study is used to examine the effects of failed FCW in the Missouri River basin. A multi-site case study is a qualitative approach that explores multiple bounded systems (cases) through in-depth data collection involving multiple sources of information (Creswell 2007, 73). These case studies qualitatively describe the effects at a given location and time to provide historical data to answer the research questions. A case study is well suited for this research because the nature of infrastructure failure does not preclude controlled behavioral effects by the population (Yin 2009, 8).

Before discussing criteria further, it is important to define what a case study is. A case study is a holistic look at a recent incident and the environment in which it took place, especially when the borders between incident and the environment are not clear (Yin 2009, 18). With FCW failure, the delineation between the incident and the environment in which it occurs are not separable. This is typically the case in a chaotic situation where there is such a devastating effect on humans.

Case Selection

The examination of three separate cases assists in answering the primary and secondary research questions. Two cases are actual flood events that occurred in the Missouri River basin, and one is theoretical, based on a natural disaster that may occur in the future. The two historical cases are the flooding of 1993 and 2011. Both of these floods resulted from above average rainfall and failed FCW in the Missouri River basin (U.S. Army Corps of Engineers 1994, 5; U.S. Army Corps of Engineers 2012b, i). These cases represent two of the most significant flood events in the Missouri River basin over the last 40 years. The final case study is a theoretical discussion of the effects of failed FCW in the Missouri River basin in the event of a large earthquake along the New

Madrid seismic zone located in Southeastern Missouri and its bordering states. This event is a possible scenario, and represents a real threat to FCW in the Missouri River basin.

The first two case studies, the floods of 1993 and 2011, represent major flooding events in the Missouri River basin. Due to the magnitude of the two floods, extensive data exists related to the effects produced by failed FCW. The New Madrid scenario is imperative to look at due to the potential catastrophic damage that may occur. An earthquake along the New Madrid seismic zone over 7.0 on the Richter Magnitude Scale occurred in 1811 resulting in significant damage to the infrastructure that existed at the time (Missouri Department of Natural Resources 2014). A momentous earthquake along the New Madrid seismic zone is a real scenario, and presents possibilities of severe damage due to the immense increase in infrastructure and population since the events in 1811.

Data-Gathering Methods

Primary data gathering utilizes open source data provided by government agencies through the Internet. Specifically, the United States Geological Survey, National Oceanic and Atmospheric Administration, United States Army Corps of Engineers (USACE), and Federal Emergency Management Agency (FEMA) provide multiple reports that each focus on the effects and recommendations post flood event. Government regulations and other strategic policy documents provide background data on requirements relating to FCW. As feasible, the author will meet with government agencies that are involved in FCW and flooding within the Missouri River basin. These agencies include the Kansas City District within USACE and FEMA Region VII. The purpose of these meetings is to collect additional data that is difficult to acquire or not available on the Internet. In order to provide additional vantage points of the effects of

failed FCW, the researcher will collect data from national and local news agencies to include televised and written stories. This collection will primarily be accomplished using Internet sources. Additionally, this will assist in providing the human reaction to the effects of failed FCW instead of only collecting numerical data samples.

Data Analysis Procedures

Data analysis in quantitative research includes preparing and organizing data, subcategorizing it by themes, and representing the data into figures, tables, or discussion (Creswell 2007, 148). Following initial collection of data, the researcher will organize electronic data into separate folders corresponding to each of the three case studies. Initially the researcher will examine each case study individually. Initial readings of the data will focus on highlighting all effects of flooding, as well as data that describes the environment. Second readings will group similar effects from different sources within each case study. This will assist in confirming effects, or producing a more holistic look at different effects that each source does not account for. Table 2 annotates data collected from the 1993 and 2011 floods. Completion of table 2 will allow all pertinent data to be centrally located in order to compare the environmental conditions and effects of both floods.

Table 2. Case Study Data, Blank			
	1993 Flood	2011 Flood	New Madrid Earthquake
What environmental conditions lead up to FCW failure?			
What FCW failed?			
How long did the flooding last?			
What economic consequences resulted from flooding?			
How many deaths resulted from flooding?			
What federal projects or changes to policy ensued because of flooding?			
What damages did FCW prevent?			

Source: Created by author

The third case study, New Madrid scenario, will take a similar approach to the first two case studies. It is more difficult to determine the effects due to the hypothetical nature of this scenario. Additionally, difficulties present themselves in differentiating between effects caused by seismic activity versus those caused by failed FCW. Table 2 assists the researcher in analyzing data. The researcher will not determine federal projects and changes to policy because of flooding or damages prevented by FCW. This scenario has not occurred since USACE incurred the authority to build and maintain structures in the Missouri River basin.

Summary

This chapter presented the research methodology utilized to complete chapter 4. Case studies present a valid approach to answering questions that typically ask questions in which the answers are not always straightforward. Human interaction and reaction, as well as the environment in which these floods occurred, make answering the primary and secondary research questions more difficult when utilizing a different methodology. The case study approach allows the inclusion of these external factors to weigh in to the conclusion and recommendations in chapter 5.

CHAPTER 4

ANALYSIS

Introduction

Chapter 4 provides the analysis of the three case studies utilized to answer the primary and secondary research questions. The primary research question is: What are the effects of failed flood control works in the Missouri River Basin? The secondary questions are: What are possible causes of flood control works failure? What are the economic effects from failed flood control works? What are the effects on human life that may result from failed flood control works? Each case study presents with an overview, followed by the findings and analysis of the information collected in accordance with table 2 presented in chapter 3 of this paper. It includes economic effects to numerous sectors, impacts on human life, required repairs following flood events, and changes to policy because of flooding. Where feasible, data presented is specifically for the Missouri River basin. As detailed in the limitations in chapter 1, the combination of some data occurs from the Missouri and Mississippi River basins.

The Flood of 1993

The first case study provides analysis of the 1993 flood that occurred in the Missouri and Mississippi River basins. This flood occurred primarily in the Middle Mississippi and Lower Missouri areas of the Mississippi River drainage basin. Widespread flooding began in mid-June and lasted through mid-September (U.S. Army Corps of Engineers 1994, 57). For the purpose of this case study, the author will look specifically at the effects of flooding in the Missouri River basin, outlined on figure 3.

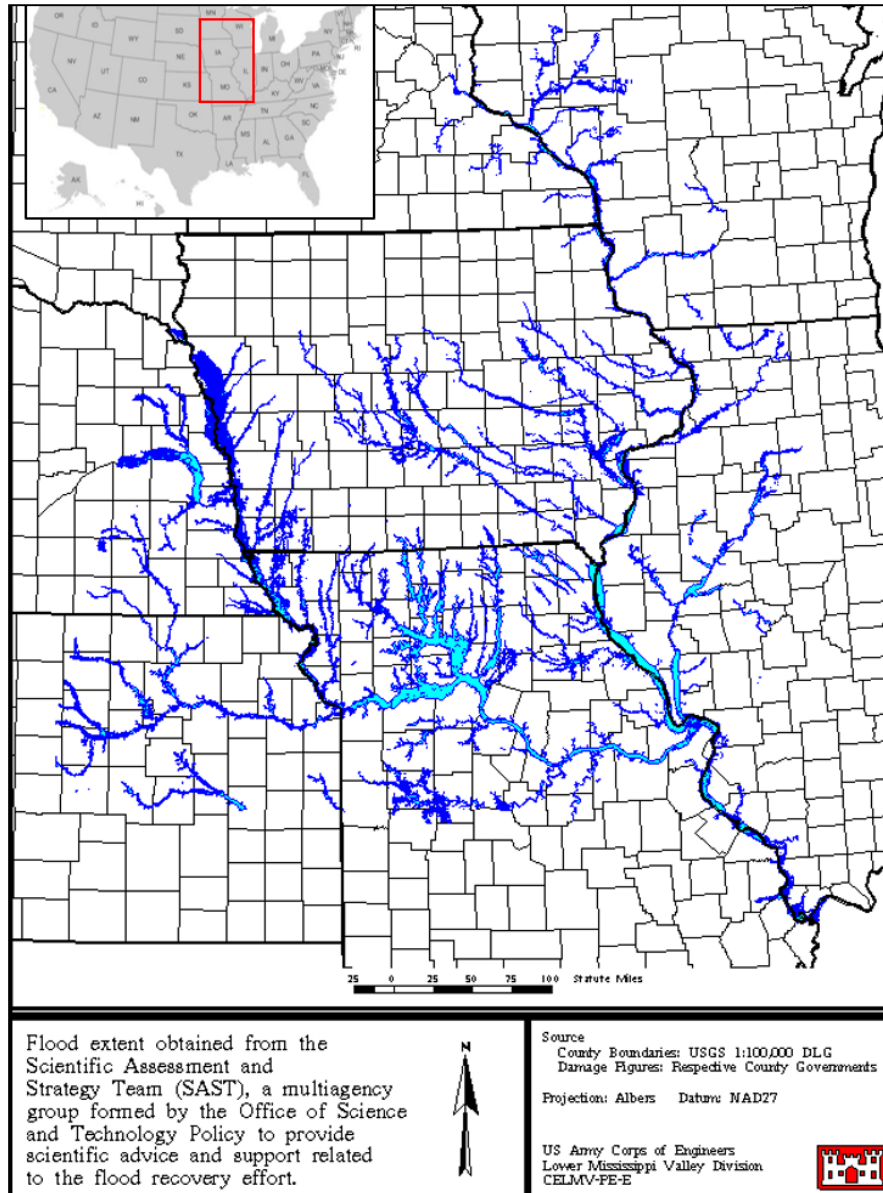


Figure 3. 1993 Flood Extent

Source: U.S. Army Corps of Engineers, 1993 Flood Data, <http://el.erdc.usace.army.mil/flood/> (accessed 17 February 2014).

What Environmental Conditions Lead to FCW Failure?

Atmospheric conditions played the predominant role in the cause of flooding in 1993. The weather pattern that lasted from June to August was the result of a large dome of stationary high pressure over the southeastern United States and a strong low-pressure system in the northern Rocky Mountains. The high-pressure system brought the warm, humid air into the region while the low-pressure system continued to spin off disturbances across the plains (U.S. Army Corps of Engineers 1994, E-16). When these two air masses collided, conditions were extremely favorable for strong storms with heavy precipitation. Because this weather pattern lasted for two months, the Midwest received rainfalls well above normal. Precipitation during the winter of 1992-93 and the spring of 1993 exceeded the average with temperatures staying below average, resulting in a high spring runoff that saturated much of the ground prior to the excessive summer rainfall (U.S. Army Corps of Engineers 1995, I-3). The combination of the high spring runoff and excess summer precipitation overwhelmed the existing flood control structures along the Missouri River and some of its tributaries. Over time, the continuous flow of water against levees resulted in structural damage due saturation and the removal of material that made up the levees.

What Flood Control Works Failed?

Along a 535-mile segment of the Missouri River from Brownsville, Nebraska to the confluence with the Mississippi River, approximately 99 percent of non-federal levees failed from breaching, overtopping, wave wash, side wash, or top wash (U.S. Army Corps of Engineers 1994, E-73). Non-federal levees typically serve agricultural purposes, and are not designed or constructed to withstand such extreme conditions.

Because of the magnitude of the flood event, these non-federal levees had little chance of withstanding the significant flows experienced along the Missouri River.

Of the federally-constructed levees in the Missouri River basin, sixty-two of the seventy-nine constrained all floodwaters during the event (Government Accountability Office 1995, 67). Of the seventeen levees that failed to contain all flood water, sixteen were overtopped, and one was overtopped followed by a breach in the levee (Government Accountability Office 1995, 31). Overtopping of a levee does not always indicate a failure. If the actual flow rate of the water is above the flow rate of design, the levee may overtop into the protected area. The one federally-constructed levee that failed during the 1993 floods was the Missouri River Levee Unit R-550. The levee, located near Brownville, Nebraska, overtopped by one to two feet, and subsequently breached on the morning of 24 July 1993 (U.S. Army Corps of Engineers 1995, 8-46). This levee unit received repairs in 1952 and 1984 using sand dredged from the river, which may have contributed to the breach on 24 July. Following the 1993 flood USACE repaired the levee with commercially purchased sand that is impervious to saturation, which should provide greater protection against failure in the future (Government Accountability Office 1995, 74).

A significant breach of a non-federally-constructed levee occurred near Saint Louis, Missouri. The Chesterfield-Monarch levee is a privately financed levee that provided 100-year flood protection to 4,240 acres in 1993, of which 1,450 acres housed over three million square feet of commercial floor space (U.S. Army Corps of Engineers 1995, 8-44). Believing the levee provided sufficient protection because it met standards for the National Flood Insurance Program, extensive development took place in the

floodplain. During the 1993 flood, waters exceeded the 100-year flood stage and caused a breach in the levee resulting in over \$200 million in damages to over two hundred commercial enterprises and related transportation facilities (U.S. Army Corps of Engineers 1995, 10-18).

How Long Did the Flooding Last?

One of the significant causes of damage during the 1993 flood was the length of time in which the Missouri River stayed above flood stage. Depending on the location along the Missouri River, the flood stage began and ended at differing dates. The Missouri River was at or above flood stage from 26 June to 6 August near Saint Joseph, Missouri, 3 July to 6 August near Kansas City, Missouri, 1 July to 16 August near Boonville, Missouri, and 2 July to 25 August near Hermann, Missouri (U.S. Army Corps of Engineers 1994, E-21). The greatest duration of flooding in the Missouri River basin occurred in Saint Charles, Missouri. The Missouri River at Saint Charles stayed at or above flood stage from 3 July to 30 August and then again from 3 September to 7 October for a total of 94 days (Larson 1995, 12). The suspension of other uses of the Missouri River occurred because of the long duration of the flood. Navigation ceased from 2 July to 20 August, for a total of 49 days on the Missouri River (U.S. Army Corps of Engineers 1995, I-2).

What Economic Consequences Resulted From Flooding?

The 1993 flood exceeded most damage estimation curves due to the extreme duration of flooding. Typically, floods of comparable height, but shorter duration, cause significantly less damage (U.S. Army Corps of Engineers 1995, 3-9). A shorter duration

flood of similar floodwater heights will cause less damage for at least two reasons. The first is that levees that failed during a longer duration flood may not fail during a short duration flood. The longer floodwaters are in contact with a levee system, the chances for failure increase due to prolonged soaking of the structure. The second reason is that floodwaters of a longer duration increase the damage to agricultural land and infrastructure due to increased sediment deposits and erosion across the area. Agriculture represented the greatest damages within the Missouri River basin during the flood event. However, across the entire region 80 percent of damage to crops resulted from losses other than flooding such as excessive rainfall with the exception of agricultural losses within USACE Kansas City District area of responsibility, where flooding caused the majority of agricultural loss (U.S. Army Corps of Engineers 1995, 3-12).

Flooding along the Missouri River also halted barge traffic from moving private and commercial goods and material. Twenty one percent of the navigation season was lost due to the flood, which is limited to parts of the year when the river does not contain ice (U.S. Army Corps of Engineers 1994, E-81). According to Dr. Phillip Baumel, a Professor in Agriculture at Iowa State University, barge traffic along the Missouri River provides \$10 million in economic benefit per year (Environmental Defense Fund 2014). This equates to roughly \$2.1 million in lost revenue to the barge industry because of flooding.

Throughout the Missouri River basin, damage occurred to many critical facilities. These facilities provide protection, transportation, and requirements for communities to survive. Table 3 depicts the damage by civil works district boundary within USACE

Northwest Division. In addition to personal property and places of business, this shows the additional affects that flooding caused communities within the Missouri River basin.

Table 3. Damage to Key Infrastructure			
Key Infrastructure	Omaha District	Kansas City District	Total
Municipal and Industrial National Pollutant Discharge Elimination System	9	18	27
Hazardous Waste Facility	-	1	1
Water Treatment Plants	-	3	3
Major Water Supply Intakes	2	6	8
Water Well Fields	-	8	8
Sewage Treatment Plants	-	3	3
Power Plants	7	2	9
Schools	-	8	8
Federal and State Bridges	26	8	34
Prisons	-	2	2
Airports	3	8	11
Fire and Police Departments	-	2	2
Military Installations	-	3	3
Communications Facility	-	1	1
Post Offices	-	13	13

Source: Created by author, utilizing data from U.S. Army Corps of Engineers, *Floodplain Management Assessment of the Upper Mississippi River and Lower Missouri Rivers and Tributaries* (Washington, DC: U.S. Army Corps of Engineers, 1995), 3-16.

Within USACE Omaha District's civil works boundary, it is estimated that over \$654 million in damages occurred to agricultural and rural areas (U.S. Army Corps of Engineers 1995, 5-5). There was over \$65 million in residential damage and another \$124 million in other urban and infrastructure damage. Emergency costs, human resource-related disaster assistance, and National Flood Insurance Program payouts totaled over \$305 million (U.S. Army Corps of Engineers 1995, 5-9). Federal Emergency

Management Agency assistance in the 137 counties alone amounted to \$78 million dollars. Of this amount, \$51.5 million was for public and private non-profit assistance and \$26.5 million was for individual assistance. The Small Business Administration provided an additional \$6.7 million in loans (U.S. Army Corps of Engineers 1994, 49).

Within USACE Kansas City District's civil works boundary, flooding resulted in estimated damages of greater than \$2.2 billion, with agricultural and rural losses totaling 66 percent of the damage (U.S. Army Corps of Engineers 1995, 5-13). At the time, the total cost of repairing federal levees was \$41.9 million. Repair costs for non-federal levees in the district, including those levees not repaired by USACE, exceeded \$300 million (U.S. Army Corps of Engineers 1994, E-95).

Within FEMA Regions VII and VIII (Missouri, Kansas, Nebraska, Iowa, North Dakota, and South Dakota), over \$745 million was expended by FEMA for public assistance, individual assistance, hazard mitigation, mission assignments, and FEMA administration costs (Federal Emergency Management Agency 2003, B-5). Because portions of Missouri and Iowa received significant flooding from the Mississippi River as well as the Missouri River, this total is higher than the costs associated with flooding in the Missouri River basin.

Within the transportation sector, the rail industry suffered devastating losses. Many of the large railroads travel through the Missouri River basin, specifically through the Kansas City area. Rail lines closed because of flooding in the Missouri River basin included Santa Fe, Burlington Northern, Chicago & North Western, Gateway Western, Norfolk Southern, Canadian Pacific, and Union Pacific (Changnon 1996, 189). Total losses from damages and lost revenues exceeded \$400 million for the rail industry during

the flood of 1993 with Burlington Northern suffering the largest loss, totaling \$132 million (Changnon 1996, 191).

During the 1993 flood, record stages occurred on the Missouri River from Saint Joseph, Missouri, to the mouth at Saint Louis, Missouri, and near record stages occurred from Nebraska City, Nebraska, to Rulo, Nebraska, resulting in total damages of approximately \$12 billion (Grigg et al. 2011, 20). Due to the extent of damages and the length of recovery, this estimate came years after the flood event ended. Other economic effects, including decreased crop yields, may take years to realize following the devastation of a flood of this magnitude.

How Many Deaths Resulted From Flooding?

Overall, the flooding that occurred on the Mississippi and Missouri rivers resulted in the death of 47 people (U.S. Army Corps of Engineers 1994, iii). Within Missouri alone, twenty-seven deaths occurred because of the flood. Of those deaths, twenty-one occurred from drowning and six were indirectly related to the floods. Those six deaths occurred through electrocution while repairing flood damaged buildings, stress-induced cardiac arrest, and trauma from motor vehicle accidents caused by diverted traffic patterns (Center for Disease Control 1993).

What Federal Projects or Changes to Policy Ensued Because of Flooding?

In the aftermath of the 1993 flood, the United States focused on flood damage reduction programs and actions required to reduce losses from flooding (Galloway 2005, 5). This flood caused the most extensive damage seen due to flooding at the time. The federal government understood that mitigating the effects of a future flood required flood

reduction programs. In response, the Administration Floodplain Task Force directed the formation of an Interagency Floodplain Management Review Committee consisting of a multi-disciplinary and interagency group of experts in fields relevant to floodplain management. Deliverables of the committee included making recommendations to changes in current policies, programs, and activities that would most effectively achieve risk reduction, economic efficiency, and environmental enhancement in the floodplain and related watersheds (Galloway 2005, 6). In June of 1994, the committee presented its findings to the Administration Floodplain Task Force, *Sharing the Challenge: Floodplain Management Into the 21st Century*. This report provided 38 recommendations in accordance with their mandate. Some of the significant recommendations were enactment of national floodplain legislation that delineates federal through local level responsibilities, enhancement of efficiency and effectiveness of the National Flood Insurance Program, and an Executive Order that clearly defines the responsibility of federal agencies to exercise sound judgment in floodplain activities (Interagency Floodplain Management Review Committee 1994, xi). The Floodplain Management Task Force established two multi-agency work groups that met over three years to address high priority recommendations from the report, including drafting a national floodplain management act to submit to Congress, revising the Floodplain Management Executive Order, and developing common procedures for federal buyout programs of flood-damaged properties. Little was formally accomplished, but federal agencies and local governments adopted a number of recommendations from the report (Wright 2000, 81).

Following the flood, considerable work was required to repair failed levees. Within USACE Omaha District, a total of 166 levees required repair, but only twenty-

nine were eligible for federal funding under Public Law 84-99 (U.S. Army Corps of Engineers 1994, 52). If the damaged levees did not have an active status in the National Levee Database discussed in chapter 1, USACE could not provide funding under Public Law 84-99.

Within USACE Kansas City District, all fifty-two federal levees required repair following the flood, of which twenty-seven sustained damage requiring Public Law 84-99 funding (U.S. Army Corps of Engineers 1994, 53). More than eight hundred non-federal levees required repair, but only 110 levees were eligible to receive funding under Public Law 84-99 (U.S. Army Corps of Engineers 1994, 53). Legal disputes over cost sharing and realignments caused delays in beginning repairs to the levees within the district (U.S. Army Corps of Engineers 1994, E-103). Overall, more than \$7.4 million dollars worth of repairs occurred to FCW in the Missouri River basin (U.S. Army Corps of Engineers 1994, 52)

In addition to FCW, navigation structures along the Missouri River also required repairs. Severe damages occurred to stone-filled dikes and revetment structures in at least forty-five locations, requiring repair or replacement (U.S. Army Corps of Engineers 1995, I-7). These structures are important for maintaining a navigable channel in the Missouri River, an important economic factor during the navigation season. In addition to navigation benefits, the structures also provide flood control by stabilizing the banks of the river.

What Damages Did FCW Prevent?

Even though significant damage occurred due to overtopping or failure of FCW within the Missouri River basin, damages would have increased dramatically without

them. The six main-stem reservoirs on the Missouri River had a significant impact on reducing flood stages downstream from Gavin's Point Dam. Without these reservoirs, the 1993 peak flood stage would have been approximately nine feet higher at Sioux City, six feet higher at Omaha, and three feet higher from Nebraska City to the confluence with the Mississippi River (U.S. Army Corps of Engineers 1994, 32). Within Omaha District civil works boundary, the six main-stem dams prevented an estimated \$980 million in damages and \$474 million in government expenditures for emergency response, disaster assistance, and indemnities (U.S. Army Corps of Engineers 1995, 9-43). Within Kansas City, six levees would have overtopped without the main-stem dams, resulting in approximately \$3 billion in damages, most occurring within Kansas City (U.S. Army Corps of Engineers 1995, I-7).

In addition to the six main-stem dams along the Missouri River, levees played an important role in reducing damages due to the 1993 flood event. Within Omaha District's boundaries, the federal agricultural levees are estimated to have prevented over \$71 million damages (U.S. Army Corps of Engineers 1995, 9-7). Within the Kansas City District, federal levees are estimated to have prevented approximately \$4.5 billion in damages (U.S. Army Corps of Engineers 1994, E-85).

The Flood of 2011

The second case study looks at the flood event that occurred in the Missouri River basin in 2011. Widespread flooding occurred June through August due to late snowmelt and above average precipitation during May (National Weather Service 2012a, vi). For the purpose of this case study, the author will look specifically at the effects of flooding in the Missouri River basin, generally displayed in figure 4.

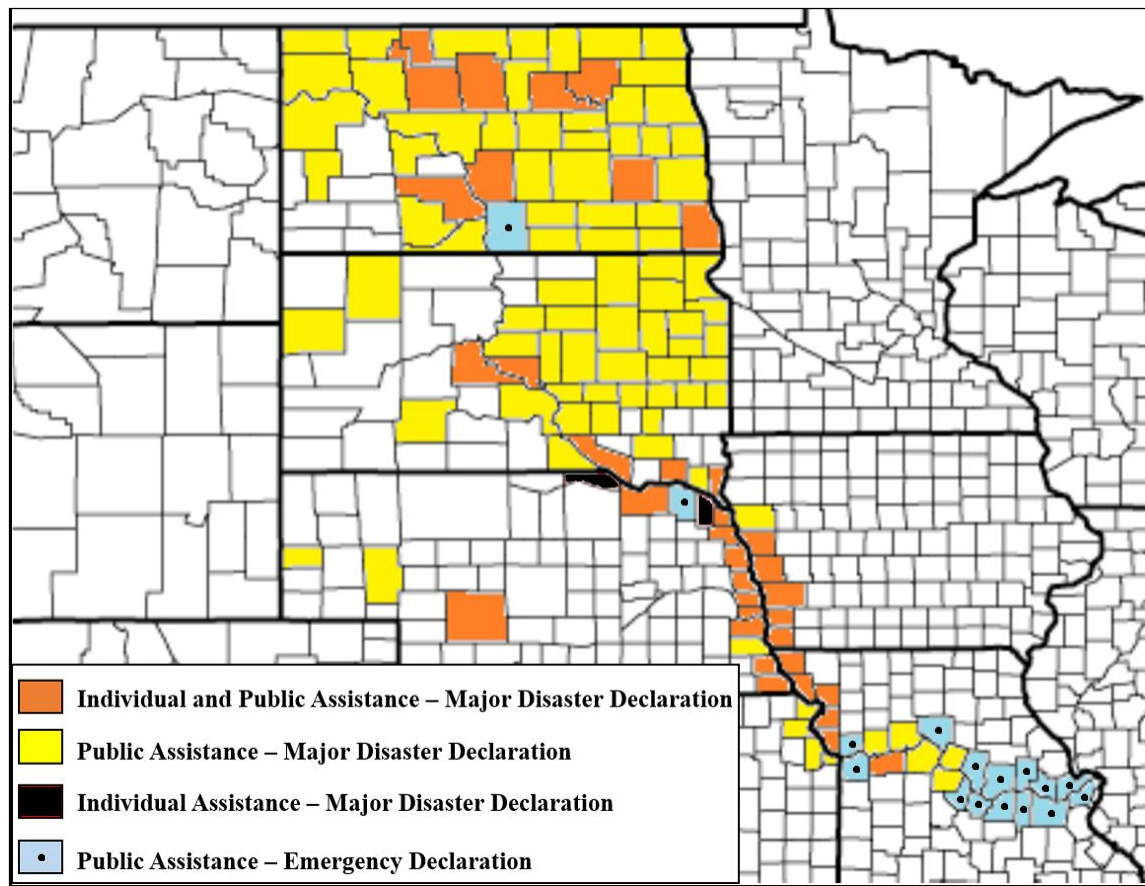


Figure 4. 2011 Missouri River Basin Flood Extent

Source: Created by author, utilizing data from Federal Emergency Management Agency, Disaster Declarations for 2011, http://www.fema.gov/disasters/grid/year/2011?field_disaster_type_term_tid_1=6837&=GO (accessed 14 April 2014); World Atlas, U.S.A. Country Map, <http://www.worldatlas.com/webimage/countrys/namerica/usstates/counties/usacountymap.htm> (accessed 14 April 2014).

What Environmental Conditions Led Up to FCW Failure?

Weather related factors began to set conditions six months before the floods of 2011 occurred. Precipitation in 2010 across the upper Missouri River basin was well above normal, resulting in soil moisture anomalies of 20 to 40 percent above normal conditions (National Weather Service 2012a, 8). As winter set in, the moisture in the soil

froze and remained through winter into spring. A La Niña weather pattern persisted throughout the winter and into spring of 2011, resulting in substantially above normal precipitation (National Weather Service 2012a, 8).

Water that enters the Missouri River typically comes during two waves, snowmelt from the Northern Plains, and Mountain snowmelt into the headwaters. Snowmelt from the plains resulted in an increased inflow of fifty percent into the Ft. Peck Reservoir (National Weather Service 2012a, 11). The Ft. Peck Reservoir is the first of six USACE mainstem dams along the Missouri River. Mountain snowpack accumulated at above average rates, but due to the La Niña weather pattern, cold temperatures and snowfall accumulations continued into May (National Weather Service 2012a, 11). Just as the above average snow accumulations began melting, significant rainfall events brought excess precipitation to the northern Missouri River basin.

Record rainfall in Wyoming, the Dakotas, and Montana began in late May, with Montana receiving over 300 percent of normal precipitation in May (National Weather Service 2012a, 14). Since the mainstem reservoirs being at or near capacity, the majority of this precipitation could only flow downstream through tributaries into the Missouri River. From the beginning of March to the end of June, approximately Forty-nine million acre-feet of runoff entered the Missouri River, overwhelming the floodplains, saturating and overtopping levee systems (U.S. Army Corps of Engineers 2012c, 2). Forty-nine million acre-feet is approximately enough to cover the entire state of Rhode Island under sixty-three feet of water.

What FCW Failed?

Levee design typically plans for direct contact with floodwaters for a few days to weeks per year before the soil becomes saturated, not the months of direct contact that occurred during the 2011 floods (U.S. Army Corps of Engineers 2012c, 5). Overall, the 2011 floods resulted in damage to approximately seventy-five federally-constructed levees and hundreds of non-federal levees due to overtopping, erosion, and under seepage (U.S. Army Corps of Engineers 2012c, 5). During the 2011 flood event, every non-federal levee from Rulo, Nebraska, to Kansas City, Missouri, overtopped or breached (National Weather Service 2012a, 31). Many of the non-federal levees along the Missouri River were to provide protection to agricultural areas, not against a flood similar to what occurred in 2011.

Most of the non-federal levees that overtopped during the 2011 flood also ultimately breached due to the lack of resiliency features such as a flattened landside slope or designed overtopping sections to resist the landward erosion caused by overtopping (U.S. Army Corps of Engineers 2012d, 139). If non-federal levees are not listed in the USACE database as active, the responsibility for repairing any damage falls on the local government, or owner in the case of private levees. North of Council Bluffs, Iowa, several levees not listed in the USACE database in an active status breached, resulting in further damage to Interstate 29 and Interstate 680 (Missouri River Flood Coordination Task Force 2012, 44). Federal government funding covers the damage to the interstates, but not repairs of the levees.

During the 2011 flood, two federally-constructed levees along the Missouri River experienced breaches. The L-575 experienced its first of two breaches on 5 June 2011,

and the L-550 experienced its first of three breaches on 23 June 2011 (U.S. Army Corps of Engineers 2012c, 19; U.S. House 2012, 91). Local citizens, county government and USACE personnel responded quickly to mitigate the breaches on L-575, resulting in the protection of Hamburg, Iowa; unfortunately the towns of Percival and Bartlett, Iowa, were inundated (Missouri River Flood Coordination Task Force 2012, 44). Estimates say 47,000 acres of crops were lost, along with damaging some of the most productive agricultural areas in the United States (U.S. House 2012, 91; U.S. Army Corps of Engineers 2012d, 25).

How Long Did the Flooding Last?

The flood of 2011 was a record 500-year event that surpassed the intended volume of the original mainstem system design by twenty percent and lasted five months (U.S. Army Corps of Engineers 2012c, 8). North Dakota was the first state to experience flooding as early as February 2011, followed by five other states within the Missouri River basin. According to FEMA, the incident periods of flooding were February 14 to 20 July in North Dakota; 11 March to 22 July in South Dakota; 24 May to 1 August in Nebraska; 25 May to 1 August in Iowa; and 1 June to 1 August in Kansas and Missouri (Federal Emergency Management Agency 2014b). By the time the flood ended, the Missouri River and its tributaries flooded portions of the United States for 169 days.

What Economic Consequences Resulted From Flooding?

Economic impacts associated with the 2011 flood on the Missouri River were extraordinary. When large scale flooding occurs, economic impacts do not appear immediately, and some effects may take years to surface. Immediate costs typically occur

from flood fighting efforts, and lost revenues to businesses in the immediate area. Larger term effects include lost crops and damage to property, as well as costs associated with the recovery effort. In the seven states affected by the 2011 Missouri River flooding, the cost of direct flood damages and response and repair activities borne by USACE was approximately \$1 billion (Grigg et al. 2011, 10). Other damages across the region resulted in an estimated \$2 billion as of May 2012, which will likely increase as more reliable data is available (National Weather Service 2012a, 67).

During the flood, USACE played a large role in flood fighting activities. During the 2011 flood event, Bismarck and Mandan, North Dakota, required USACE assistance with flood fighting efforts, including constructing miles of temporary earthen levees and sandbagging to protect critical infrastructure such as an elementary school, and many residential areas (U.S. Army Corps of Engineers 2012d, 14). The United States Army Corps of Engineers assisted the cities of Pierre and Fort Pierre, South Dakota, through the construction of temporary clay levees, which protected water and sewage facilities (U.S. Army Corps of Engineers 2012d, 16).

Protecting key infrastructure remains a top priority during flood fighting efforts. The loss of certain facilities or infrastructure may put additional strain on local populations, hinder recovery efforts, or cause serious health concerns and death. Table 4 describes the key infrastructure within the area affected by the 2011 flood. Of note, the flood had considerable impact on the energy and transportation sectors within close proximity to the Missouri River.

Table 4. Key Infrastructure Within Flooded Area			
Facility	Omaha District	Kansas City District	Total
Energy Producing and Storage Plants (Non-Nuclear)	3	1	4
Nuclear Energy Producing and Storage Plants	2	-	2
Energy Infrastructure (Pipelines, Oil Wells etc.)	461	297	758
Emergency Response (Hospitals, Police etc.)	1	1	2
Schools	8	-	8
Airports	2	6	8
Bridges	253	149	402
Railroad Miles	111	141	252
Interstate Miles	73	7	80
Highway Miles	36	25	61

Source: Created by author, utilizing data from U.S. Army Corps of Engineers, *Missouri River Flood 2011 Vulnerabilities Assessment Report Volume II: Technical Report* (Portland, OR: U.S. Army Corps of Engineers, 2012), 21.

In and around Omaha, Nebraska, the energy sector faced considerable risk due to flooding. The Omaha Public Power District incurred costs of over \$100 million during the 2011 flood (U.S. Army Corps of Engineers 2012d, 21). A considerable amount of that cost resulted from the flood fighting efforts at the Fort Calhoun Nuclear Generating Station, which provides approximately fifteen percent of the Omaha Public Power District's generation capacity (Omaha Public Power District 2014). The cost to protect that one facility was \$36.4 million (U.S. Army Corps of Engineers 2012d, 21). At the same time, the Omaha Public Power District protected the Nebraska City Coal-Fired Power Plant from flooding. This power generation plant produces close to twenty percent of the district's power, and incurred over \$17 million in expenditures to remain in operation during the flood (U.S. Army Corps of Engineers 2012d, 22; Omaha Public

Power District 2014). Less than one hundred miles south of Fort Calhoun, the Nebraska Public Power District engaged in flood-fighting activities to protect the Copper Nuclear Power Station near Brownsville, Nebraska, expending over \$2.5 million (U.S. Army Corps of Engineers 2012d, 22).

The transportation sector saw significant effects due to the 2011 floods within the Missouri River basin. Road networks and rail infrastructure were especially hard hit. Within the affected area, federal aid to highway repairs totaled \$322 million, not counting the costs required to repair federally-maintained interstates (Missouri River Flood Task Force 2011, 16). Over fifty-four miles of crucial interstates saw closures for greater than one hundred days between Missouri, Nebraska, and Iowa, resulting in over \$19 million in repair costs (U.S. Army Corps of Engineers 2012d, 23). This figure does not represent the cost associated with detours required to local commuters and long-haul transportation.

Rail infrastructure damages and mitigation costs accounted for a large portion of the transportation sector costs associated with flooding. Over two hundred and fifty miles of railroad tracks required raising track sections, building of temporary berms, and repair to damaged tracks resulting in costs of over \$300 million (U.S. Army Corps of Engineers 2012c, 3). Amtrak also suspended service on routes through Minnesota, North Dakota, and eastern Montana due to the Missouri River flood, resulting in thousands of hours of work and millions of dollars in repair costs (U.S. Army Corps of Engineers 2012d, 25).

Damages occurred to multiple airports because of the 2011 flood. Eppley Airfield in Omaha, Nebraska, and Sherman Army Airfield on Fort Leavenworth, Kansas, both incurred costs due to flooding. Eppley Airfield remained open, but it required a massive flood-fighting effort totaling around \$26 million (U.S. Army Corps of Engineers 2012d,

23). Sherman Army Airfield, which serves the military and local community, flooded after a breach in a local levee. The flooding resulted in approximately \$4.5 million in damages and months of downtime to the airfield (U.S. Department of the Army 2014).

How Many Deaths Resulted From Flooding?

In total, the floods of Missouri River Basin claimed five lives and led FEMA to issue disaster declarations in each state along the Missouri River. Two of these flood deaths were vehicle related and occurred directly on or near the main-stem Missouri River (National Weather Service 2012b, 5). Authorities said a man who was working on a levee near a rock quarry in Fort Calhoun died on June 9 after his truck rolled (The Omaha World Herald 2014). A culvert failure approximately five miles from the Missouri River in South Dakota took the lives of two women. The culvert failure resulted in a large sinkhole on Bureau of Indian Affairs Route 10, which both women drove into on the morning of June 22 (Red River Broadcast Company 2011).

What Federal Projects or Changes to Policy Ensued Because of Flooding?

The 2011 flood along the Missouri River and its tributaries caused significant damage to flood control structures. In order to prepare for the next flood event, these structures and others that maintain navigability along the Missouri River required repairs. The Missouri River Bank Stabilization and Navigation Projects are important to both flood prevention and navigation within the Missouri River. The project limits the amount of lateral movement of the river, which in turn, prevents bank erosion and maintains the navigation channel (U.S. Army Corps of Engineers 2012d, 159). Estimates to repair the

project figured about \$30 million, and consisted mostly of rock revetments and dikes (U.S. Army Corps of Engineers 2012d, 159).

At the end of the 2011 flood event, all six mainstem dams on the Missouri River received repair assessments. These assessments were critical in determining damages caused by the excessive volume of water and flow rates endured during the year. Damage occurred on all six dams to include spillway damage and under seepage issues on five of the dams, all which could lead to the eventual failure of the dams if not repaired (U.S. Army Corps of Engineers 2012d, 50).

Within USACE Omaha and Kansas City Districts, seventeen levees required Class I critical repairs. Class I levees require urgent and compelling repairs due to the likelihood of inundation and associated consequences according to the levee safety action classification (U.S. Army Corps of Engineers 2014g). Repair was required for seepage and erosion for nine levee sections, and for breaches on seven levee sections (Missouri River Flood Task Force 2011, 27). The North Kansas City Levee Unit, which protects more than \$2 billion of infrastructure, required repairs due to slope stability (American City Business Journals 2014). The repairs on this levee completed in early 2012, and cost \$450 thousand (U.S. Army Corps of Engineers 2012a, 1). This project provided critical protection to numerous facilities within the industrial area of North Kansas City.

Policy changes because of the 2011 floods are still forthcoming. A lawsuit is currently filed against the United States Government for the perceived mismanagement of the Missouri River. Filed on 5 March 2011, the claim states:

Plaintiffs bring their claims for a taking of their land and other property without just compensation, by means of a significant and deliberate departure by the U.S. Army Corps of Engineers (“the Corps” or “Corps”) from its decades-old

policies and practices regarding the management of the Missouri River (“the River”), including its management of the Missouri River Mainstem Reservoir System (“the System”) and the Missouri River Bank Stabilization and Navigation Project (“BSNP”). Specifically, in order to restore habitat of certain native species in the Missouri River Basin (“the Basin”), the Corps departed from its longstanding management policies and practices when it knew that the direct, natural, probable, and foreseeable result of that departure would be increasingly frequent and severe flooding of Plaintiffs’ land and property. (United States v. Ideker Farms, Inc. et al. 2014, 4)

Based on the outcome of the lawsuit, changes may or may not occur in USACE’s management principles of the Missouri River mainstem system. An independent review, titled *The Review of the Regulation of the Missouri River Mainstem Reservoir System During the Flood of 2011*, found no evidence that USACE personnel attempted to do anything other than to operate the system using the best available methods and to minimize the overall negative consequences (Grigg et al. 2011, 84).

What Damages Did FCW Prevent?

In spite of the magnitude of the 2011 flood, the existing infrastructure functioned as designed and prevented nearly \$8.2 billion in damages across the Missouri River basin (U.S. Army Corps of Engineers 2012b, 7). The six mainstem dams on the Missouri River combined with USACE levees and channel improvement projects accounted for 89 percent of this estimate, and USACE emergency operations activities accounted for another 6 percent (U.S. Army Corps of Engineers 2012d, 27).

Within the metropolitan areas of the Missouri River and one of its tributaries, the Kansas River, federally-constructed levees provide flood risk management to the working environment and residences of nearly 200-thousand individuals (U.S. Army Corps of Engineers 2012d, 156). One of the major metropolitan areas along the Missouri River is Kansas City, Missouri. Because of the large concentration of industrial and commercial

activities in this area, the largest prevention figures are located there. Between USACE dams, levees and channel improvements, Missouri avoided over \$3.5 billion in damages (U.S. Army Corps of Engineers 2012d, 27). Because of the hard work by local communities, USACE-supported emergency operations prevented over \$126 million in damages within North Dakota, and over \$500 million in damages across the Missouri River basin (U.S. Army Corps of Engineers 2012d, 27).

New Madrid Scenario

The New Madrid Seismic Zone is approximately forty miles wide and two hundred miles long, encompassing parts of eight states including Southeastern Missouri (Mid-America Earthquake Center 2014). The first large earthquake recorded in American history along the New Madrid fault occurred in 1811 with aftershocks continuing into 1812. Passengers on the maiden voyage of the first steamboat on the Mississippi River woke to find that the island they had moored to the night before had disappeared because of liquefaction. Reports of boat captains and others on the Mississippi River stated the earthquakes caused banks to cave into the river, created temporary waterfalls, and even caused the Mississippi River to flow backwards (U.S. Geological Survey 2011, 4).

Figure 5 shows a history of activity within the New Madrid seismic zones. The red circles indicate earthquakes larger than 2.5 magnitudes that occurred from 1974 to 2002, and green circles denote earthquakes that occurred prior to 1974 (U.S. Geological Survey 2014).

Scenario MMI Hazard Map NM NE Segment, M 7.7

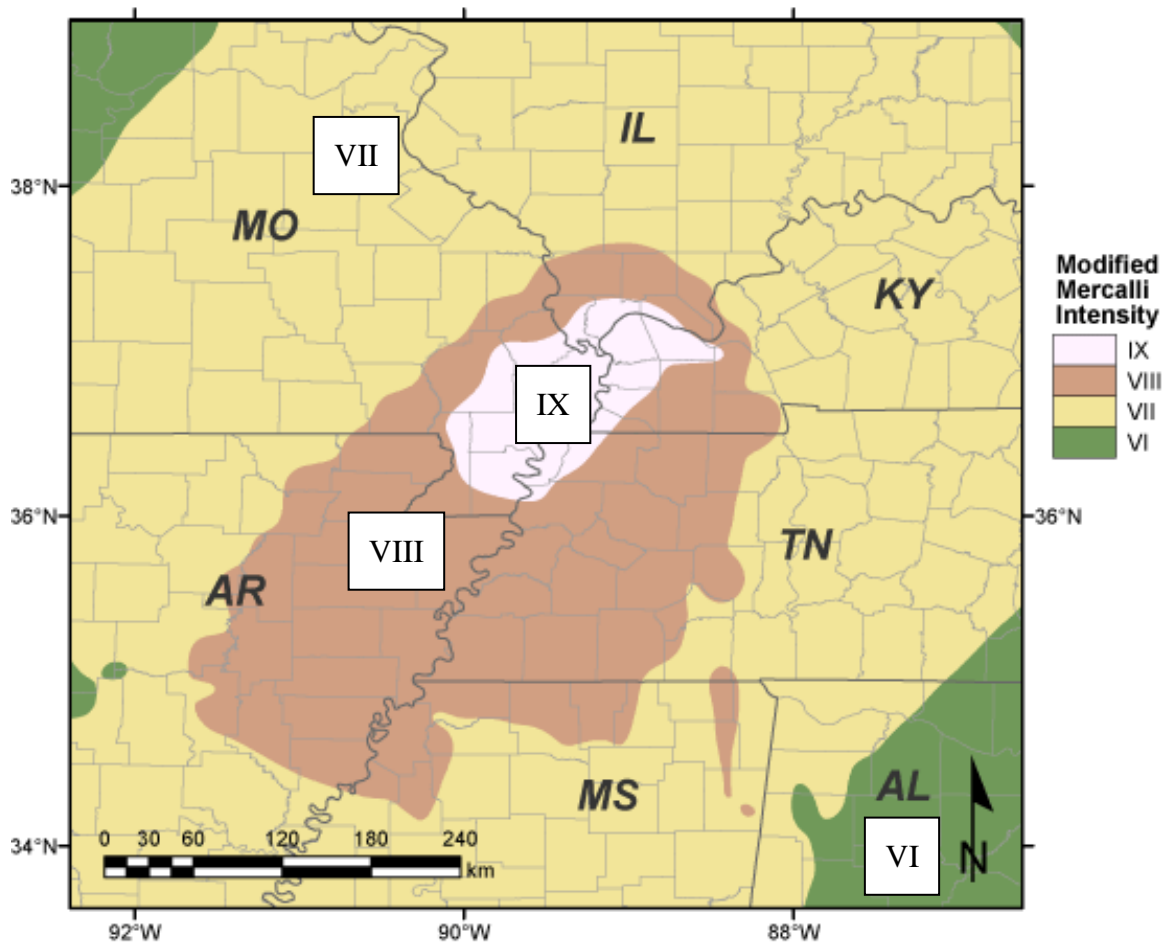


Figure 5. New Madrid Seismic Zone

Source: U.S. Geological Survey, Regional Hazard Maps and Data Download, <http://earthquake.usgs.gov/regional/ceus/products/regional.php> (accessed 13 May 2014).

What Environmental Conditions Might Lead Up to FCW Failure?

The main environmental condition that would cause FCW to fail during an earthquake along the New Madrid seismic zone is a process called *liquefaction*.

Liquefaction occurs when strength and stiffness of a soil is reduced by earthquake shaking or other rapid loading (University of Washington 2014). This may cause levees along the Missouri River to lose strength and possibly fail. Figure 6 illustrates the liquefaction susceptibility along the Missouri River for the counties impacted by a magnitude 7.7 earthquake along the New Madrid fault. This shows that the likeliness of FCW failure within the Missouri River Basin would only occur within sixty miles of the confluence of the Mississippi River.

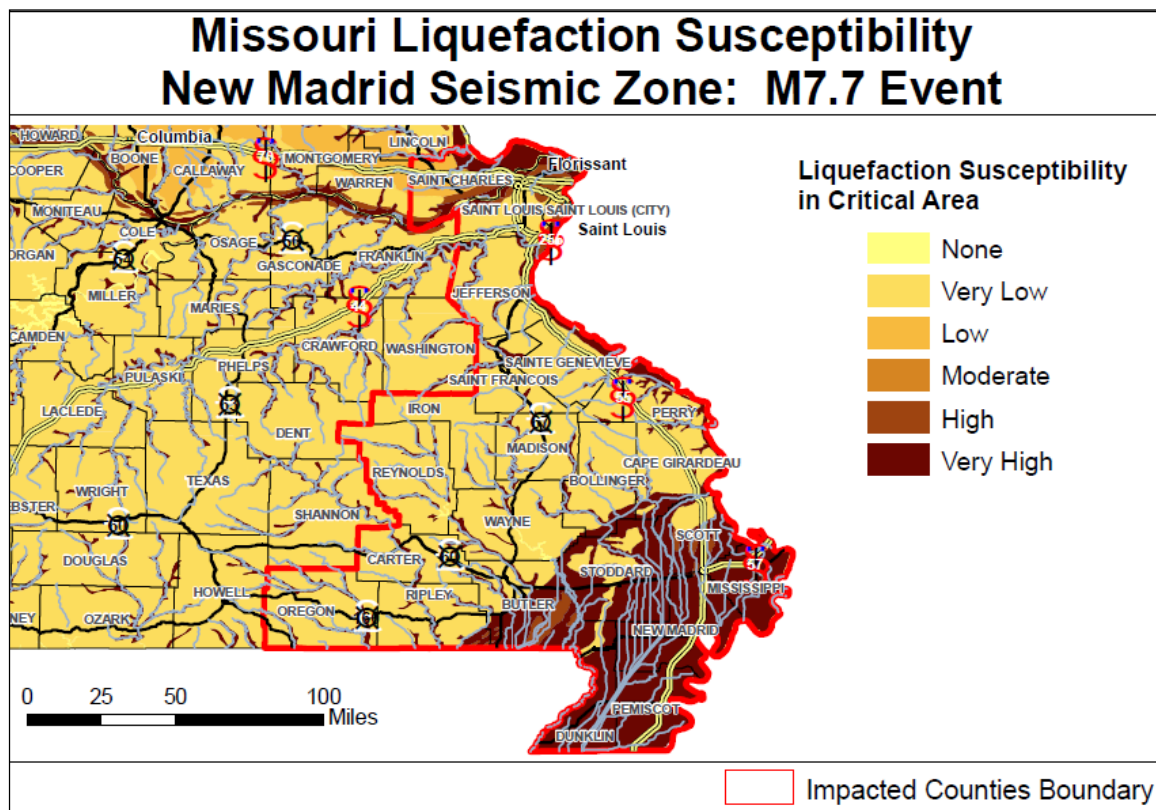


Figure 6. Missouri Liquefaction Susceptibility

Source: Elnashai et al., *Impact of New Madrid Seismic Zone Earthquakes on the Central USA*, vol. 2 (Urbana, IL: University of Illinois, 2009), A7-210.

What FCW Might Fail?

The most likely FCW to fail in the event of a major earthquake along the New Madrid fault are levee systems or earthen dams. These structures have an increased risk of failure due to earthen construction that is susceptible to liquefaction. The soil surrounding the Missouri River is comprised of sediments and deep deposits of soft soils that are notorious sources of liquefaction, or the tendency of the saturated, unconsolidated soils to take on a liquid-like behavior (Cleveland, Elnashai, and Pineda 2007, 35). This research will focus on FCW along the first sixty miles of the Missouri River from the confluence with the Mississippi. This area is the most likely to be impacted as depicted in figure 6 by the red boundary highlighting the impacted counties. Because the six mainstem dams along the Missouri River are located in North and South Dakota, it is highly unlikely that any damage would occur due to seismic activity originating from the New Madrid area. However, dozens of smaller dams exist within the impacted counties of the Missouri River basin shown in figure 6 (U.S. Army Corps of Engineers 2014f). While all dams near urban areas pose some risk, none of these dams are anywhere close to the risk associated with a failure of the six mainstem dams on the Missouri River. There are thirteen levees that protect Saint Charles and Saint Louis Counties along the Missouri River as displayed in figure 7. These levees protect over 69,000 acres; most of which is comprised of agricultural area, with the exception of the industrial area protected by the Chesterfield-Monarch and Earth City levees (U.S. Army Corps of Engineers 2014e).

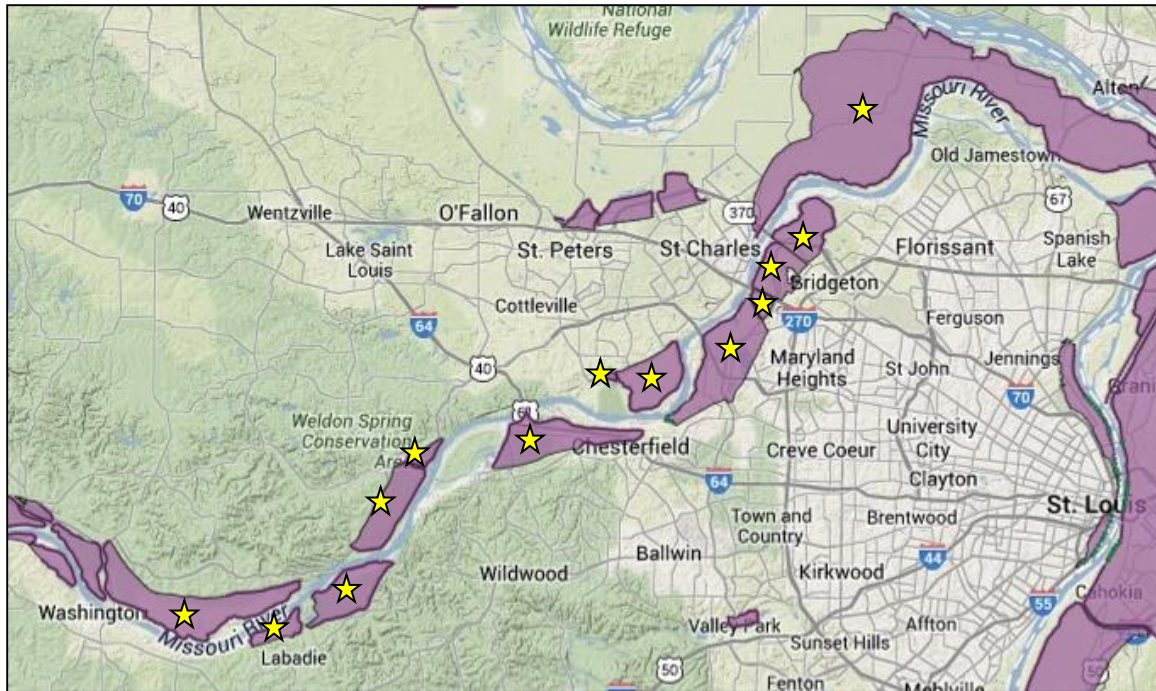


Figure 7. Levee Protection near Saint Louis, Missouri

Source: U.S. Army Corps of Engineers, National Levee Database, http://nld.usace.army.mil/egis/nlde_prod.cm2.map?map=PUBLIC&p_MapExt=-91.253564,38.507124,-89.800622,39.155408&p_layers=leveescenterln,leveesclosurestructureln,leveesfloodwallln,leveesprotectedarea_public&p_basemap=GEC (accessed 6 May 2014).

How Long Would the Flooding Last?

Immediate flooding would only be likely within the Missouri River basin if river levels were at flood stage during the time of a major earthquake in the New Madrid seismic zone. Even if levees fail during an earthquake, areas in Saint Louis and Saint Charles County, Missouri, would remain unflooded from the Missouri River in all probability. Levees do not remain in contact with water during normal stage heights. Levees are flood control structures that protect vulnerable areas as rivers overflow their

banks. However, if these levees sustained undetected damage, flooding could occur the next time waters rise above flood level.

What Economic Consequences Might Result from Flooding?

Flooding only affects Scott County within Missouri according to the Mid-America Earthquake Center (Elnashai et al. 2009a, 83). Scott County, Missouri, is south of the Missouri River basin in the upper Mississippi River basin. As seen during the 1993 flood, a breach in the Chesterfield-Monarch levee resulted in over \$200 million in damages to over two hundred commercial enterprises and related transportation facilities (U.S. Army Corps of Engineers 1995, 10-18). Regardless if floodwaters damage local communities and infrastructure, a severe earthquake would require extensive assessments and repairs to the levee systems along the Missouri River near its mouth. After the 1993 flood, the Chesterfield-Monarch levee received repairs and improvements to protect against a 500-year flood, which cost over \$70 million (Saint Louis Post-Dispatch 2014). Because of this increased protection, more business is located within the area protected by the levee. Since 1993, at least three times the number of businesses now operate in the area (Saint Louis Dispatch 2014). Based on the \$200 million in damages in 1993 and an increase by 300 percent in the business sector, this equates to roughly \$981 million in potential damage when inflation is applied using the Bureau of Labor Statistics inflation calculator.

How Many Deaths Might Result From Flooding?

Within the Missouri River basin, it is unlikely that deaths will result from failed FCW. As described above, without the presence of waters in the Missouri River or its

tributaries at flood stage prior to the earthquake, it is unlikely that flooding will occur. However, estimates expect up to 86,000 total casualties with deaths tolls reaching approximately 3,500 from other causes related to the earthquake (Elnashai et al, 2009a, 82).

Flood Event Comparisons

Overall, both flood events in 1993 and 2011 resulted in billions of dollars in damages. Costs associated with damages to urban areas are higher than rural or agricultural areas, but rural areas susceptible to flooding within the Missouri River basin are much more common. Without FCW in the Missouri River basin, incurred damages would result in more than twice the costs observed during both flood events. Both floods resulted in damage to numerous key infrastructures that support local communities as well as national transportation sectors. Effects to nuclear and non-nuclear power production resulted in hundreds of millions of dollars in mitigation and repair costs. The transportation sector incurred costs in the hundreds of millions of dollars to interstate, rail, air, and barge commerce. The floods of 1993 and 2011 resulted in deaths, either directly or indirectly. In 1993, over twenty people died because of the flood, while five died because of the 2011 flood. Both floods resulted in millions of dollars in damage to FCW across the Missouri River basin. These costs were borne directly by USACE in some instances and by local communities with partial assistance by FEMA in the remainder of instances. Based on the most developed area at risk by failed FCW from the Missouri River, A catastrophic earthquake at the New Madrid seismic zone could result in nearly \$1 billion from flood damage alone. While this has a relatively low chance of

occurring simultaneously with an earthquake, damage to FCW could result in flooding months to years after the earthquake.

Table 5. Damage Comparisons			
	1993 Flood	2011 Flood	New Madrid Earthquake
Total damages (\$1,000)	\$12,000	\$3,100*	\$981**
Damages prevented (\$1,000)	\$13,720	\$8,200	N/A
* Estimated costs based on USACE repairs and preliminary data			
** Estimated based on 1993 flood, and 300% growth in business sector			

Source: Created by author

Summary

Chapter 4 provided analysis of three separate case studies: two of historical floods, and one of a very real scenario that the United States could see within this century. Overall, the impacts of failed FCW in the Missouri River basin are quite extensive. With the amount of development along the Missouri River and its tributaries over the past century, a vast amount of population and key infrastructure are within the reach of floodwaters. Both the 1993 and 2011 floods resulted in billions of dollars spent on emergency mitigation, response, recovery, and impacts to local economies. The elimination of effects due to flooding is impractical; however, FCW assist in reducing the damages caused by flooding. Chapter 5 will provide conclusions and recommendations because of this research.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Introduction

This study sought to determine the effects of failed flood control works (FCW) in the Missouri River basin. In order to answer the primary research question, three secondary questions brought depth and clarity to the subject. The secondary questions are: What are possible causes of FCW failure? What are the economic effects from failed FCW? What are the effects on human life that may result from failed FCW?

A qualitative study consisting of a multi-site case study provided examples of the effects of failed FCW. Two historical examples included the flood of 1993 and the flood of 2011. In addition, a scenario involving significant seismic activity along the New Madrid fault attempted to determine secondary effects of failed FCW because of an earthquake. Chapter 1 provided background information on the subject as well as different jurisdictions involved with FCW. Chapter 2 consisted of a literature review of federal government policy and law, scholarly works including books and journals, and a review of literature specific to the three cases analyzed in chapter 4. Chapter 3 consisted of the research methodology utilized in determining the answers to the primary and secondary research questions. Chapter 4 is the results of the multi-site case study that looked at the flooding in 1993 and 2011, and a possible future event of a catastrophic earthquake along the New Madrid fault. Chapter 5 includes an overview of the findings from chapter 4, and the conclusions and recommendations of the study.

Findings

What Are the Possible Causes of Failed FCW?

Flood control works can fail in many different ways. In the case studies analyzed in chapter 4, the majority of failures resulted from overtopping or breaching of levees. A levee is not considered as failed from a technical perspective just because it is overtopped. In order to be considered failed, it must be overtopped during a flow rate less than the design specifications of the levee. The second most frequent cause of failure was levee breaches. Breaches occurred in both locally-constructed and federally-constructed levees along the Missouri River. Constant contact between levees and floodwaters, as well as overtopping, was the primary reason for breaches to occur. As water seeps into the levee, the levee becomes less stable, and may fail before the flood waters recede.

The conditions that led up to waterways in the Missouri River basin reaching flood stage included a combination of weather related conditions. The first was above normal precipitation during the winter and spring before flooding occurred, resulting in excessive runoff due to melting snow in the headwaters of the Missouri River. This resulted in decreased flood control capacity in the six mainstem dams along the Missouri River. The second condition that existed was excessive precipitation days or weeks before the flood event peaked. Within the Missouri River basin, precipitation well above normal occurred resulting in large volume of tributary runoff that entered the Missouri River.

What Are the Economic Effects From Failed FCW?

Wide scale flooding resulted in billions of dollars in damage to communities within the Missouri River basin. Because of the prime soil conditions that exist along the

Missouri River, agricultural commerce is very common. This results in large losses to the agriculture industry from flooding. Flood control works in many agricultural areas are not designed and built to protect against floods of the magnitude seen in 1993 and 2011, which resulted in flood levels reaching the 100-year and even 500-year flood levels in some locations (U.S. Army Corps of Engineers 1994, 29; U.S. Army Corps of Engineers 2012c, 8). In addition to agricultural losses, significant damages occurred to community and transportation infrastructure within the Missouri River basin. Sewage treatment plants, power plants, and community facilities including first responder headquarters, schools, and hospitals received damage. Within the transportation sector railroads saw damages over a third of a billion dollars in 1993 and 2011. Airports, interstates, and highways also incurred damages. Hundreds of bridges, including those along interstates, and hundreds of miles of primary roads resulted in hundreds of millions in damages.

What Are the Effects on Human Life That May Result From Failed FCW?

Flooding effects humans on many different levels: everyday life is interrupted, businesses fail, and possessions are ruined. Harsh living conditions exist that the population is unaccustomed, including disruption in basic needs such as drinking water and power. The greatest impact on human life that results from flooding is death. The floods in 1993 and 2011 both caused loss of life. Some of the deaths in both flood events resulted from drowning, but deaths also resulted from secondary means in 1993 and 2011. In 1993, people lost their lives due to electrocution while repairing damaged facilities. In both floods, changes in traffic patterns or in extreme cases large sinkholes caused from flooding resulted in fatal traffic accidents.

Conclusion

Overall, failed FCW can result in billions of dollars due to damages, response, and recovery efforts. Depending on the location, severity, and duration of flooding, this number will fluctuate greatly. Damages are greater in urban areas compared to rural areas. This results from a higher density of population and infrastructure in urban areas. For example, the population in Jackson County, Missouri, at the confluence of the Missouri and Kansas Rivers is 1,115 persons per square mile, while Richardson County, Nebraska, which includes the city of Rulo, has a population density of 15 persons per square mile (U.S. Census Bureau 2014). Because of the increased population density, the number of homes, businesses, and supporting infrastructure increases dramatically.

This is important to understand for decision-making involved in risk mitigation strategies. During the 2011 floods, agricultural and rural areas were intentionally flooded near the confluence of the Mississippi and Ohio Rivers (outside of the Missouri River basin). The United States Army Corps of Engineers breached the Birds Point Levee, which resulted in the flooding of 130,000 acres of farmland and ninety homes near Wyatt, Missouri, in order to protect Cairo, Illinois, a city eight times larger (Public Broadcasting Service 2014).

Overall, FCW in the Missouri River basin provides protection to valuable land, personal property, and economic resources. It is critical that public and governmental leaders understand its importance, and provide funding to operate and maintain these systems. Much of the FCW infrastructure is aging, and requires increased funding in order to maintain integrity in order to provide protection in the future. The six mainstem dams along the Missouri River were constructed between 1933 and 1964 with the Fort

Peck Dam being the first constructed (U.S. Army Corps of Engineers 1993, vi). Aging infrastructure, such as the Fort Peck Dam, requires careful monitoring and increased costs to repair in order to prevent failure.

This multi-site case study depicts a typology of the effects of failed FCW. It allows the study to be broken into smaller, more manageable parts in order to increase the understanding of how failed FCW impacts the United States. Through increased understanding and the identification of the different effects of failed FCW, it is possible to model potential impacts for future floods. In the analysis of historical cases, this typology allowed the determination of the effects of failed FCW within the Missouri River basin during two separate occurrences of failed FCW. This facilitated the modeling of a future scenario of failed FCW near the confluence of the Missouri and Mississippi Rivers resulting from a major seismic event along the New Madrid fault.

While this study did determine that a major seismic event along the New Madrid fault could result in upwards of \$1 billion in damages due to failed FCW in the Missouri River basin, additional modeling is required to limit the deviation. In order to narrow the range of error in this estimate, multiple areas require further detail. First, within the potential floodplain, more detail is required on the worth of infrastructure in regards to local business, residential, and supporting community infrastructure. Second, further study is required on the impacts to FCW because of liquefaction. Based on the composition of the levees within this area, liquefaction will affect these structures differently. Field research must occur in order to determine the susceptibility and impact due to liquefaction more accurately. Third, the long-term impacts to business in the area require further research. Depending on the type of facility, and economic impact of each

business, effects may be further reaching and longer term. While some the disruption of some businesses within the area may affect the local economy, some may create a regional effect.

Areas for Further Study

Flood control works failure taxes local, state, and federal resources, strains economies, and devastates communities. While this study provided answers to the primary and secondary research questions, greater reliability is possible by analyzing additional cases. In addition, our understanding of the effects of failed FCW during the 2011 flood in the Missouri River basin is incomplete because the flood occurred less than three years prior to this study, and all of the economic consequences are not yet known.

Multiple areas exist for further study on the topic of failed FCW in the Missouri River basin. Further economic analysis of the effects of flooding will provide needed data for future policy decisions. This data will enable policy makers to understand what funding is required to maintain these structures sufficiently, and where to increase protection from flooding. Additionally, it will assist in decision-making regarding the percentage of storage devoted to flood control versus other statutory requirements of the mainstem dams along the Missouri River such as navigation, hydropower, recreation, fish and wildlife, and water supply. Another area for further study involves ways to mitigate the effects of failed FCW in the Missouri River basin. Additional research may also identify better emergency mitigation measures. Finally, additional research should be conducted to refine the environmental effects of failed FCW in the Missouri River basin. Failed FCW causes significant changes to agricultural land. Historically, flooding within areas adjacent to rivers created rich soil that improved the agricultural properties of the

land. In many cases where FCW failed, agricultural land becomes unusable due to large sand deposits left behind from overtopped or breached levees.

A different approach that might provide additional insight to this research is to analyze a specific area in which FCW failure occurred on multiple occasions. For instance, the Missouri River Levee Unit-550 has failed on three separate occasions since 1952 (U.S. Army Corps of Engineers 2012d, 143). By comparing and contrasting these three separate events, additional insights may arise that provide useful in future FCW projects and policies.

Summary

Chapter 5 summarized the findings associated with the primary and secondary research questions analyzed in chapter 4. In addition, it provided recommendations for future areas of study related to the effects of failed FCW, and offered a different approach in order to provide greater fidelity to determining the effects of failed FCW in the Missouri River basin. As with most natural disasters, there is no way of controlling the environment or eliminating all effects, but determining ways to mitigate those effects is critical. Because failed FCW results in great economic and emotional strain, frequently resulting in human deaths, it is important to understand the effects in order to increase mitigation efforts in the future.

In 1962, President John F. Kennedy made the following statement at the dedication ceremony of the Oahe Dam along the Missouri River in South Dakota: We take for granted these miracles of engineering. And too often we see no connection between this dam right here and our Nation's security and our leadership all around the world. The facts of the matter are that this dam and many more like it are essential to the expansion and growth of the American economy as a measure that Congress is now considering. And this dam and others like it are essential to our national strength and security, as any military alliance or missile complex. (U.S. House 2011, 1)

As President Kennedy stated, infrastructure included in FCW is vital to the Nation's interests, and we must take necessary measures to ensure it provides benefits instead of increasing risks.

REFERENCE LIST

- American City Business Journals. 2014. Levees protect Kansas City area, but they're neither cheap nor easy to build. <http://www.bizjournals.com/kansascity/print-edition/2011/07/29/levees-protect-kansas-city-area-but.html?page=all> (accessed 20 April 2014).
- Association of State Dam Safety Officials. 2014. About ADSO. <http://www.damsafety.org/about/?p=3a16ecf7-35c5-4c31-97d2-b22740e144b5> (accessed 14 February 2014).
- Center for Disease Control. 1993. Flood-related mortality—Missouri, 1993. 10 December. <http://www.cdc.gov/mmwr/preview/mmwrhtml/00022339.htm> (accessed 16 April 2014).
- Changnon, Stanley A., ed. 1996. *The great flood of 1993: Causes, impacts, and responses*. Boulder, CO: Westview Press.
- Cleveland, Lisa J., Amr S. Elnashai, and Omar Pineda. 2007. *New Madrid seismic zone catastrophic earthquake response planning*. Urbana, IL: University of Illinois. <https://www.ideals.illinois.edu/handle/2142/8787> (accessed 14 March 2014).
- Creswell, John W. 2007. *Qualitative inquiry and research design: Choosing among five approaches*. 2nd ed. Thousand Oaks: Sage Publications.
- d'Arcy, Michael, Michael E. O'Hanlon, Peter R. Orszag, Jeremy Shapiro, and James B. Steinberg. 2006. *Protecting the homeland, 2006/2007*. Washington, DC: Brookings Institution Press.
- Elnashai, Amr S., Lisa J. Cleveland, Theresa Jefferson, and John Harrauld. 2009a. *Impact of New Madrid seismic zone earthquakes on the central USA*, Vol. 1. Urbana, IL: University of Illinois. <https://www.ideals.illinois.edu/handle/2142/14810>. (accessed 14 March 2014).
- . 2009b. *Impact of New Madrid seismic zone earthquakes on the central USA*, Vol. 2. Urbana, IL: University of Illinois. <https://www.ideals.illinois.edu/handle/2142/14810>. (accessed 14 March 2014).
- Environmental Defense Fund. 2014. EDF report: Missouri River barges provide little benefit to farmers. <http://www.edf.org/news/edf-report-missouri-river-barges-provide-little-benefit-farmers> (accessed 16 April 2014).
- Executive Office of the President of the United States. 2003a. *The national strategy for the physical protection of critical infrastructures and key assets*. Washington, DC: Government Printing Office. http://www.dhs.gov/xlibrary/assets/Physical_Strategy.pdf (accessed 27 September 2013).

- . 2003b. Homeland Security Presidential Directive (HSPD) 7: *Critical infrastructure protection plans to protect federal critical infrastructures and key resources*. Washington, DC: Government Printing Office. <http://www.whitehouse.gov/sites/default/files/omb/memoranda/fy04/m-04-15.pdf> (accessed 25 September 2013).
- . 2010. *National security strategy*. Washington, DC: Government Printing Office. http://www.whitehouse.gov/sites/default/files/rss_viewer/national_security_strategy.pdf (accessed 27 September 2013).
- Federal Emergency Management Agency. 2003. *The 1993 great midwest flood: Voices 10 years later*. Washington, DC: Department of Homeland Security. <http://www.fema.gov/national-flood-insurance-program/1993-great-midwest-flood-voices-10-years-later> (accessed 2 April 2014).
- . 2011. *FEMA strategic plan fiscal years 2011-2014*. Washington, DC: Department of Homeland Security. <http://www.fema.gov/fy-2011-2014-strategic-plan> (accessed 2 February 2014).
- . 2012. *Strategic plan for the national dam safety program: Fiscal years 2012 through 2016*. Washington, DC: Department of Homeland Security. http://www.fema.gov/media-library-data/8025e6039b9aebfa22e9f378347149c4/NDSP%20Strategic%20Plan_FEMA%20P-916.pdf (accessed 8 November 2013).
- . 2013. About FEMA. April 30. <http://www.fema.gov/about-fema> (accessed 2 November 2013).
- . 2014a. About the agency. July 22. <http://www.fema.gov/about-agency> (accessed 4 January 2014).
- . 2014b. Disaster declarations by year. <http://www.fema.gov/disasters/grid/year> (accessed 1 February 2014).
- Frolov, Konstantin V., and Gregory B. Baecher, eds. 2006. *Protection of civilian infrastructure from acts of terrorism*. Dordrecht: Springer.
- Galloway, Gerald E. Jr. 2005. Corps of Engineers responses to the changing national approach to floodplain management since the 1993 Midwest flood. *Journal of Contemporary Water Research and Education* no. 130 (March): 5-12.
- Grigg, Neil, Cara McCarthy, Bill Lawrence, and Darwin Ockerman. 2011. *Review of the regulation of the Missouri River mainstem reservoir system during the flood of 2011*. Portland, OR: U.S. Army Corps of Engineers. <http://www.nwd-mr.usace.army.mil/rcc/MRFTF/docs/MRIndependentReviewPanel.pdf> (accessed 13 March 2014).

- Interagency Floodplain Management Review Committee. 1994. *Sharing the challenge: floodplain management into the 21st century*. Washington, DC: Government Printing Office. http://www.floods.org/PDF/Sharing_the_Challenge.pdf (accessed 16 April 2014).
- Kruse, C. James, Zafarbek Ahmedov, Bruce McCarl, Ximing Wu, and James Mjelde. 2001. America's locks and dams: A ticking time bomb for agriculture?. http://www.unitedsoybean.org/wp-content/uploads/2013/07/Americas_Locks_And_Dams.pdf (accessed 3 November 2013).
- Larson, Lee W. 1995. *The great USA flood of 1993*. Silver Spring, MD: National Weather Service. <http://www.engr.colostate.edu/~jsalas/us-italy/papers/11larson.pdf> (accessed 15 April 2014).
- Lewis, Ted G. 2006. *Critical infrastructure protection in homeland security: Defending a networked nation*. Hoboken, NJ: Wiley-Interscience.
- Mid-America Earthquake Center. 2014. Earthquake hazard and impact in the new madrid region. http://www.in.gov/dhs/files/NMSZ_threats_flyer.pdf (accessed 27 March 2014).
- Missouri Department of Natural Resources. 2014. Facts about the new madrid seismic zone. <https://www.dnr.mo.gov/geology/geosrv/geores/techbulletin1.htm> (accessed 26 March 2014).
- Missouri River Basin Interagency Roundtable. 2011. MRBIR 12 October 2011 meeting summary. Video Teleconference/Webinar. <http://projects.ecr.gov/mrbir/pdfs/MRBIR%20VTC%20Summary101211.pdf> (accessed 16 April 2011).
- Missouri River Flood Coordination Task Force. 2012. *Missouri River flood coordination task force report*. Johnston, IA: Iowa Homeland Security and Emergency Management. <http://publications.iowa.gov/14198/> (accessed 12 April 2014).
- Missouri River Flood Task Force. 2011. Missouri River flood task force kickoff meeting October (powerpoint). Lecture, Crowne Plaza Hotel, Denver, CO, 21 October. <http://www.nwd-mr.usace.army.mil/rcc/MRFTF/docs/Federal%20presentations.pdf> (accessed 7 April 2014).
- Moteff, John, and Paul Parfomak. 2004. CRS Report for Congress, *Critical infrastructure and key assets: Definition and identification*. <http://www.fas.org/sgp/crs/RL32631.pdf> (accessed 9 November 2013).
- National Corn Growers Association. 2014. Economic benefits of improving the upper Mississippi and Illinois Rivers. <http://www.ncga.com/topics/transportation/upper-mississippi-illinois-river-economic-benefits> (accessed 13 February 2014).

- National Weather Service. 2012a. *The Missouri/Souris River floods of May–August 2011*. Silver Spring, MD: National Weather Service. http://www.nws.noaa.gov/os/assessments/pdfs/Missouri_floods11.pdf (accessed 29 March 2014).
- . 2012b. *United States flood loss report–water year 2011*. Silver Spring, MD: National Weather Service. <http://www.nws.noaa.gov/hic/summaries/WY2011.pdf> (accessed 16 April 2014).
- O'Hanlon, Michael E., Peter R. Orszag, Ivo H. Daalder, I. M. Destler, David L. Gunter, Robert E. Litan, and James B. Steinberg. 2002. *Protecting the American homeland: A preliminary analysis*. Washington, DC: Brookings Institution Press.
- Omaha Public Power District. 2014. Facilities. http://www.oppd.com/aboutus/22_002701 (accessed 17 April 2014).
- Public Broadcasting Service. 2014. Levee blast floods Missouri town, spares others along Mississippi River. <http://www.pbs.org/newshour/rundown/levee-blast-floods-missouri-town-spares-others-along-the-mississippi> (accessed 06 May 2014).
- Purpura, Philip P. 2007. *Terrorism and homeland security: An introduction with applications*. Boston: Butterworth-Heinemann.
- Red River Broadcast Company. 2011. Names released in sinkhole deaths. June 22. http://www.kdlt.com/index.php?option=com_content&task=view&id=10134&Itemid=72 (accessed 19 April 2014).
- Saint Louis Post Dispatch. 2014. Lessons from the great flood: Some defenses strengthened, other land returned to rivers. http://www.stltoday.com/news/local/metro/lessons-from-the-great-flood-some-defenses-strengthened-other-land/article_cabf7844-1042-556b-925e-f3defcab4a20.html (accessed 6 May 2014).
- Sparger, Adam, and Nick Marathon. 2013. *Transportation of U.S. grains: A modal share analysis*. U.S. Dept. of Agriculture, Agricultural Marketing Service, May. <http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5090455> (accessed 29 October 2013).
- U. S. Army Corps of Engineers. 1993. *Big dam era: A legislative and institution history of the pick-sloan Missouri basin program*. Omaha, NE: U.S. Army Corps of Engineers. www.nwdmr.usace.army.mil/rcc/reports/pdfs/BigDamEra.pdf (accessed 24 March 2014).
- . 1994. *The great flood of 1993 post-flood report*. Saint Paul, MN: U.S. Army Corps of Engineers. www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA419436 (accessed 13 November 2013).
- . 1995. *Floodplain management assessment of the upper Mississippi River and lower Missouri Rivers and tributaries*. Washington, DC: U.S. Army Corps of

- Engineers. <http://www2.mvr.usace.army.mil/UMRS/NESP/Documents/Floodplain%20Management%20Assessment.pdf> (accessed 13 March 2014).
- . 2001a. Engineer Pamphlet (EP) 500-1-1, *Emergency employment of Army and other resources*. Washington, DC: U.S. Army Corps of Engineers. <http://www.publications.usace.army.mil/USACEPublications/EngineerPamphlets.aspx> (accessed 15 February 2014).
- . 2001b. Engineer Regulation (ER) 500-1-1, *Emergency employment of Army and other resources*. Washington, DC: U.S. Army Corps of Engineers. <http://www.publications.usace.army.mil/USACEPublications/EngineerRegulations.aspx> (accessed 15 February 2014).
- . 2010. Flood emergency assistance. http://www.sjgov.org/oes/forms/PL84-99_brochure.pdf (accessed 1 April 2014).
- . 2012a. *2011 Missouri River levee rehab update*. Kansas City, MO: U.S. Army Corps of Engineers. http://www.nwk.usace.army.mil/Portals/29/docs/emergencymanagement/leveerehab/North_Kansas_City_Template.pdf (accessed 20 April 2014).
- . 2012b. *Post 2011 flood event analysis of Missouri River mainstem flood control storage*. Portland, OR: U.S. Army Corps of Engineers. <http://www.nwd-mr.usace.army.mil/rcc/reports/pdfs/Post2011FloodEventAnalysisofMainstemFloodControlStorage.pdf> (accessed 13 November 2013).
- . 2012c. *Missouri River flood 2011 vulnerabilities assessment report volume i: Summary*. Portland, OR: U.S. Army Corps of Engineers. <http://cdm15141.contentdm.oclc.org/cdm/compoundobject/collection/p266001coll1/id/2187/rec/2237> (accessed 21 March 2014).
- . 2012d. *Missouri River flood 2011 vulnerabilities assessment report volume II: Technical report*. Portland, OR: U.S. Army Corps of Engineers. <http://cdm15141.contentdm.oclc.org/cdm/compoundobject/collection/p266001coll1/id/2187/rec/1> (accessed 21 March 2014).
- . 2014a. Civil works. <http://www.usace.army.mil/Missions/CivilWorks.aspx> (accessed 5 January 2014).
- . 2014b. Improving transportation. <http://www.usace.army.mil/About/History/BriefHistoryoftheCorps/ImprovingTransportation.aspx> (accessed 5 January 2014).
- . 2014c. Welcome to the Corps of Engineers 1993 flood data. <http://el.erdc.usace.army.mil/flood/> (accessed 17 February 2014).
- . 2014d. Northerstern division history. <http://www.nwd.usace.army.mil/About/History.aspx> (accessed 26 March 2014).

- . 2014e. National levee database. <http://nld.usace.army.mil/egis/f?p=471:58:1194862640275401::NO> (accessed 31 March 2014).
- . 2014f. National inventory of dams. <http://geo.usace.army.mil/pgis/f?p=397:1:1686850632735001::NO::> (accessed 2 April 2014).
- . 2014g. Levee safety action classification. <http://www.nwo.usace.army.mil/Media/FactSheets/FactSheetArticleView/tabid/2034/Article/10360/levee-safety-action-classification.aspx> (accessed 19 April 2014).
- U.S. Census Bureau. 2014. State and county quick facts. <http://quickfacts.census.gov/qfd/index.html> (accessed 1 May 2014).
- U.S. Congress. 1996. *National Dam Safety Program Act of 1996*, H.R. 3602, 104th Cong., 2nd sess. June 6. Washington, DC: Government Printing Office. <https://www.govtrack.us/congress/bills/104/hr3602/text> (accessed 8 February 2014).
- . 2000. *Disaster Mitigation Act of 2000*, Public Law 106-390, 106th Cong. October 30. Washington, DC: Government Printing Office. <http://www.fema.gov/media-library/assets/documents/4596?id=1935> (accessed 8 February 2014).
- . 2001. Uniting and strengthening American by providing appropriate tools required to intercept and obstruct terrorism (USA PATRIOT Act) Act of 2001, Public Law 107-56. U.S. Statutes at Large 115 (2001): codified at U.S. Code 42 (2001), §5195c. Washington, DC: Government Printing Office. <http://www.gpo.gov/fdsys/pkg/PLAW-107publ56/pdf/PLAW-107publ56.pdf> (accessed 9 November 2013).
- . 2002. *Homeland Security Act of 2002*, Public Law 107-296, 107th Cong. November 25. Washington, DC: Government Printing Office. http://www.dhs.gov/xlibrary/assets/hr_5005_enr.pdf (accessed 27 September 2013).
- . 2006. *Post Katrina Emergency Management Reform Act of 2006*, S.3721, 109th Cong., 2nd sess. July 25. Washington, DC: Government Printing Office. <https://www.govtrack.us/congress/bills/109/s3721>. (accessed 4 January 2014).
- . 2007. *National Levee Safety Program Act of 2007*, H.R. 1587, 110th Cong., 1st sess. March 20. Washington, DC: Government Printing Office. <https://www.govtrack.us/congress/bills/110/hr1587/text> (accessed 8 February 2014).
- . 2013. *Robert T. Stafford Disaster Relief and Emergency Assistance Act*, as Ammended, Public Law 93-288, 113th Cong. January 29. Washington, DC: Government Printing Office. http://www.fema.gov/media-librarydata/138315366995521f970b19e8eaa67087b7da9f4af706e/stafford_act_booklet_042213_508e.pdf (accessed 9 October 2013).

- U.S. Department of the Army. 2001a. Engineer Publication (EP) 500-1-1, *Civil emergency management program – procedures*. Washington, DC: U.S. Department of the Army. http://140.194.76.129/publications/eng-pamphlets/EP_500-1-1/EP_500-1-1.pdf (accessed 8 February 2014).
- . 2001b. Engineer Regulation (ER) 500-1-1, *Civil emergency management program*. Washington, DC: U.S. Department of the Army. http://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_500-1-1.pdf (accessed 4 February 2014).
- . 2011. Engineer Regulation (ER) 500-1-28, *National response planning guide*. Washington, DC: U.S. Department of the Army. http://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_500-1-28.pdf (accessed 4 February 2014).
- . 2014. Sherman Army Airfield air, sediments tested as flood waters recede. September 8, 2011. http://www.army.mil/article/65167/Sherman_Army_Airfield_air__sediments_tested_as_flood_waters_recede/ (accessed 17 April 2014).
- U.S. Department of Homeland Security. 2008. National incident management system. <http://www.fema.gov/national-incident-management-system> (accessed 4 February 2014).
- . 2009. *National infrastructure protection plan: Partnering to enhance protection and resiliency*. Washington, DC: Department of Homeland Security. http://www.dhs.gov/xlibrary/assets/NIPP_Plan.pdf (accessed 2 October 2013).
- . 2010. *Dams sector-specific plan: An annex to the national infrastructure protection plan of 2009*. Washington, DC: Department of Homeland Security. <http://www.dhs.gov/xlibrary/assets/nipp-ssp-dams2010.pdf> (accessed 2 October 2013).
- . 2011a. *Estimating economic consequences for dam failure scenarios*. Washington, DC: Department of Homeland Security. <http://www.damsafety.org/media/Documents/Security/DamsSectorConsequenceEstimation-EconomicConsequences.pdf> (accessed 2 October 2013).
- . 2011b. *Estimating loss of life for dam failure scenarios*. Washington, DC: Department of Homeland Security. <http://www.damsafety.org/media/Documents/Security/DamsSectorConsequenceEstimation-LossofLife.pdf> (accessed 2 October 2013).
- . 2012. *Strategic plan: Fiscal years 2012 through 2016*. Washington, DC: Department of Homeland Security. <https://www.dhs.gov/sites/default/files/publications/DHS%20Strategic%20Plan.pdf> (accessed 8 November 2013).

- . 2013. *National response framework*, 2nd ed. Washington, DC: Department of Homeland Security. <http://www.fema.gov/media-library/assets/documents/32230?id=7371> (accessed 4 February 2014).
- . 2014a. Homeland Security Department components. <http://www.dhs.gov/department-components> (accessed 4 January 2014).
- . 2014b. *National infrastructure protection plan*. Washington, DC: Department of Homeland Security. <https://www.dhs.gov/national-infrastructure-protection-plan> (accessed 1 February 2014).
- U.S. Geological Survey. 2011. General information product 134: 20 cool facts about the new madrid seismic zone. January 10, 2013. <http://pubs.usgs.gov/gip/134/> (accessed 24 March 2014).
- . 2014. Regional hazard maps and data download. March 21. <http://earthquake.usgs.gov/regional/ceus/products/regional.php> (accessed 13 May 2014).
- U.S. Government Accountability Office. 1995. *Midwest flood: Information on the performance, effects, and control of levees*. Washington, DC: U.S. Government Accountability Office. <http://www.gao.gov/products/RCED-95-125> (accessed 3 April 2014).
- U.S. House. 2011. Subcommittee on Water Resources and Environment. The Missouri River Flood: An Assessment of the River Management in 2011 and Operational Plans for the Future Hearing, 30 November 2001. Washington, DC: Government Printing Office. <http://www.gpo.gov/fdsys/pkg/CHRG-112hhrg71415/pdf/CHRG-112hhrg71415.pdf> (accessed 27 March 2014).
- U.S. Joint Chiefs of Staff. 2013. Joint Publication (JP) 3-28, *Defense support of civil authorities*. Washington, DC: U.S. Joint Chiefs of Staff. <http://www.dtic.mil/doctrine/doctrine/doctrine.htm> (accessed 15 October 2013).
- U.S. National Archives and Records Administration. 1999. *Code of federal regulations. Title 33, navigation and navigable waters*. Washington, DC: Government Printing Office. <http://www.gpo.gov/fdsys/pkg/CFR-1999-title33-vol1/content-detail.html> (accessed 5 January 2014).
- U.S. Senate. 2007. *Hurricane Katrina: A nation still unprepared: Special report of the committee on homeland security and governmental affairs, United States Senate, together with additional views*. Washington, DC: Government Printing Office. <http://www.gpo.gov/fdsys/pkg/CRPT-109srpt322/pdf/CRPT-109srpt322.pdf> (accessed 12 October 2013).
- United States v. Ideker Farms, Inc. et al. 2014. Case Number 1:14-cv-00183-LJB, filed 5 March 2014, by Polsinelli PC and Cohen, Milstein, Sellers and Toll PLLC.

- <http://www.missouririverflooding.com/SiteAssets/SitePages/Pleadings/Complaint.pdf> (accessed 20 April 2014).
- University of Washington. 2014. What is soil liquefaction?. <http://www.ce.washington.edu/~liquefaction/html/what/what1.html> (accessed 20 April 2014).
- Vennapusa, Pavana, David White, and Kelly Miller. 2013. *Western Iowa Missouri River flooding—geo-infrastructure damage assessment, repair and mitigation strategies*. Ames, IA: Center for Earthworks Engineering Research. http://www.intrans.iastate.edu/research/documents/research-reports/draft_iowa_flood_damage_w_cvr.pdf (accessed 4 April 2014).
- Wright, James M. 2000. *The nation's responses to flood disasters: A historical account*. Madison, WI: Association of State Floodplain Managers. http://www.floods.org/PDF/hist_fpm.pdf (accessed 16 April 2014).
- Yin, Robert K. 2009. *Applied social research methods series*. 4th ed. Vol. 5, Case Study Research: Design and Methods. Los Angeles, CA: Sage Publications.